European Commission

JRC TECHNICAL REPORTS

Results of the IET-ENEA implementation of the JRC-ENEA Memorandum of Understanding

Edited by: Heinz Ossenbrink and Gian Piero Celata

Co-edited by: Patrizia Pistochini and Fabio Monforti-Ferrario

2014

Report EUR 26723 EN

ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Joint Research Centre

European Commission
Joint Research Centre
Institute for Energy and Transport

Contact information
Patrizia Pistochini
Address: ENEA, Via Enrico Fermi 2749, 21027 Ispra (VA), Italy
E-mail: patrizia.pistochini@enea.it
Tel.: +39 0332 788253

Fabio Monforti-Ferrario
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 450, 21027 Ispra (VA), Italy
E-mail: fabio.monforti-ferrario@ec.europa.eu
Tel.: +39 0332 783996

http://iet.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/
http://www.enea.it/

JRC 91059

EUR 26723 EN

ISBN 978-92-79-39140-8 (PDF)
ISBN 978-92-79-39141-5 (print)

ISSN 1831-9424 (online)
ISSN 1018-5593 (print)

doi: 10.2790/28962 (online)

Luxembourg: Publications Office of the European Union, 2014

Abstract
This report describes the projects of the collaboration between the ENEA and the Joint Research Centre's Institute of Energy and Transport (IET), their status and the results achieved.
Since the collaboration formally started in 2008, many projects have been undertaken and concluded, often with remarkable results. However, many of the people involved have not been made aware of these results, and neither has a wider audience.
This report is intended to fill that gap and to illustrate the richness of results that such a collaboration can achieve.
The report is also proof of a concept: how to generate added value and tangible synergies when parts of two very large research organisations embark on a formal collaboration. The editors hope it will serve a number of purposes. First, to provide a comprehensive overview and stock-taking of the projects and results achieved. Second, and probably more important, to encourage all staff of both organisations to undertake further interesting projects and to share knowledge, skills, data and facilities.

Results of the IET-ENEA implementation of the JRC-ENEA Memorandum of Understanding (MoU)

Contents

Foreword

This report describes the projects of the collaboration between ENEA and the Joint Research Centre's Institute of Energy and Transport (IET), their status and the results achieved.

Heinz Ossenbrink

Since the collaboration formally started in 2008, many projects have been undertaken and concluded, often with remarkable results. However, many of the people involved have not been made aware of these results, and neither has a wider audience. This report is intended to fill that gap and to illustrate the richness of the results that such a collaboration can achieve. No extra funding or other benefits have been provided to the IET or ENEA for producing this joint report.

Gian Piero Celata

The report is also proof of a concept: how to generate added value and tangible synergies when parts of two very large research organisations embark on a formal collaboration. The editors hope that it will serve a number of purposes. First, to provide a comprehensive overview and stock-taking of the projects and results achieved. Second, and probably more important, to encourage all staff of both organisations to undertake further interesting projects and to share knowledge, skills, data and facilities.

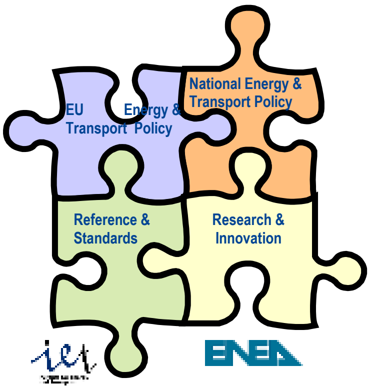
But third, and most of all, this report is a 'thank-you'; an appreciation of the results achieved and in particular a declaration of respect for the commitment of all those involved.

We both also want to express our gratitude to Patrizia Pistochini of ENEA for her effective coordination and constant patience with the many scientists involved. Without her 'human touch', many projects would not have yielded results, and this report would not be in your hands.

Heinz Ossenbrink
Gian Piero Celata

Introduction

This annual collaboration report describes the progress, results and impact of the common projects, until autumn 2013.



Since the inception of the collaboration in September 2008, a number of collaborative projects have been undertaken, particularly in the fields of photovoltaics, energy efficiency and biofuels. All projects have been based on a ‘Technical Annex’, describing the objectives, expected deliverables and content of each project.

On 17 March 2010, a general Memorandum of Understanding JRC-ENEA was signed by Mr Giovanni Lelli, Commissioner ENEA and Mr Roland Schenkel, Director General for JRC; Mr Massimo Busuoli and Mrs Marina Leonardi for the ENEA and Mr Giancarlo Caratti di Lanzacco and Mr David Wilkinson for the JRC were appointed as coordinators.

Giancarlo Caratti di Lanzacco

The MoU includes the following topics:

1. Energy;
2. Environment;
3. Security;
4. High-performance scientific computing (HPC), in particular GRID computing;
5. Nuclear sector, in particular security;

Massimo Busuoli

On 16 July 2012, new technical annexes for Energy were elaborated, with the view of focusing on projects where the JRC and ENEA expertise would be complementary, and which are of priority for both institutions. ENEA has deep scientific expertise, often based on laboratory work, and insight into Italian energy policy. The JRC has more expertise at the European level and connections with future policy agendas, and it contributes more broadly to innovation.

Collaboration status

The detailed descriptions in this document are based on input from the research groups involved on both sides. They reflect the continuation of successful collaboration in 2010/11, but also focus on a few select topics that correspond to new strategic areas where the JRC-IET and ENEA are developing complementary knowledge. Consequently, not all the proposed research programmes can be included in this review of the 2012 work programme.

New annexes

The six new technical annexes were launched in autumn 2012, and operated until the end of 2013. Their titles are:

- Photovoltaic (PV) electricity, including new materials and products;
- Bioenergy;
- SETIS;
- Net zero energy buildings;
- Mapping of wind resources;
- E-mobility;
- System adequacy in the power sector.

Staff involved

In terms of human resources, overall the JRC committed about 10 person-months for 2012. ENEA committed 16, including six from Patrizia Pistochini for overall coordination and being responsible for the SETIS technical annex.

Annex	JRC person-months	ENEA person-months
Photovoltaic	2	3
Biomass & Wind	3	4
NZEB	2	4
E-Mobility	4	4
SETIS	0.5	6
Power Systems	3	2
	11.5	21 (+2)

Table A: Staff involved in the Technical Annexes autumn 2012–winter 2013

The collaboration team

Programme management

Massimo Busuoli | ENEA — Coordinator of the Memorandum of Understanding JRC-ENEA
Giancarlo Caratti di Lanzacco | JRC — Coordinator of the Memorandum of Understanding JRC-ENEA

Governance

Gian Piero Celata | ENEA — UTTEI | Head Advanced Technologies for Energy and Industry Technical Unit
Heinz Ossenbrink | JRC — IET — REU | Head Renewable Energies Unit — Institute for Energy and Transport

Liaison officer ENEA | JRC

Patrizia Pistochini | ENEA — UTTEI-SISP

Scientists

TA1 — Photovoltaics

- Giovanna Adinolfi | ENEA — UTTP-FOTO
- Raffaele Fucci | ENEA — UTTP-FOTO
- Roberto Galleano | JRC — IET - REU
- Giorgio Graditi | ENEA — UTTP-FOTO
- Robert Kenny | JRC — IET - REU
- Harald Muellejans | JRC — IET - REU
- Matt Norton | JRC — IET - REU
- Michele Pellegrino | ENEA — UTTP-FOTO
- Tony Sample | JRC — IET - REU
- Nigel Taylor | JRC — IET - REU
- Willem Zaaiman | JRC — IET - REU

TA3 - Bioenergy

- Giacobbe Braccio | ENEA — UTTRI
- Jean-Francois Dallemand | JRC — IET - REU
- Fabio Monforti Ferrario | JRC — IET – REU
- Vincenzo Motola | JRC — IET - REU
- Maria Teresa Petrone | ENEA — UTTRI
- Nicolae Scarlat | JRC — IET - REU

TA4 — SETIS

- Patrizia Pistochini | ENEA — UTTEI-SISP
- Christian Thiel | JRC — IET - ESEU
- Evangelos Tzimas | JRC — IET - ESEU

TA6 — Net Zero Energy Building

- Paolo Bertoldi | JRC — IET - REU
- Hans Bloem | JRC — IET - REU
- Gaetano Fasano | ENEA — UTEE-ERT
- Alessandra Scognamiglio | ENEA — UTTP-FOTO

TA8 — E-mobility

- Antonino Genovese | ENEA — UTTEI-VEBIM
- Harald Scholz | JRC — IET - STU
- Giorgio Martini | JRC — IET - STU

TA9 — Wind energy

- Massimo D'Isidoro | ENEA —- UTVALAMB-AIR
- Fabio Monforti Ferrario | JRC — IET - REU
- Lina Vitali | ENEA — UTVALAMB-AIR
- Thomas Huld | JRC — IET - REU

TA10 — System Adequacy in the Power System

- Francesco Gracceva | JRC — IET - ESU
- Maria Rosa Virdis | ENEA — UCSTUDI-AS

Conclusions

In general, the collaboration has been very successful. A number of common scientific papers have been published, and team members have attended workshops and seminars and made contributions to international conferences. Some plans have not been realised, but this was mostly due to a lack of resource availability for some of the very forward-looking projects.

From the point of view of staff resources, the collaboration could be considered resource-efficient, because the person-years committed amounted only to about one for the JRC and two for ENEA. However, much more significant was the involvement of more than 30 scientists. This explains the richness of the results, which is well documented by the high number of publications and conference contributions, and in particular the workshops and meetings organised.

Three factors must be highlighted as fundamental to the success of the collaboration:

1. Good organisation in terms of setting objectives, describing the project deliverables and following up;
2. Contact between the scientists involved and the continual exchange of views, data and results in many meetings, phone calls and video-conferences;
3. The positive influence of the temporary JRC staff, who had previously worked at ENEA, their contacts or existing strong links and the 'chemistry' between the people involved, were valuable.

The JRC and ENEA appear very different in terms of organisation, legal position, financing and resources. However, there are a number of similarities around the issues affecting publically financed research centres, leading to uncertainties of resource allocation and managerial commitment.

A clear asset in this collaboration has been the way in which the strong and often rigid policy-focus of the JRC has complemented the ENEA's focus on research, technology and laboratory work. When both orientations were common ingredients, the projects yielded the best results.

The way forward

This well-established, long-standing research collaboration could in future be enhanced or adapted along three dimensions:

- More common 'exploratory' research projects on a small scale. These could tap into the possibility of sharing laboratories and combining scientific expertise, without the need for immediate policy relevance. Emphasis would be placed on the richness of ideas, creativity and innovation.

- More use of some excellent ENEA facilities contributing to the policy objectives of the JRC. This could, in some instances, avoid duplicated investments at the JRC and justify the co-financing of ENEA facilities.

- More temporary exchanges of staff on both sides, for limited periods of between one week and one month. This possibility would allow a kind of 'mini-sabbatical' for scientists and contribute to establishing personal relationships, which are of such importance for successful, common projects.

Regarding future research topics, screening of the current technical annexes is recommended. This would potentially suggest opportunities for deeper collaboration and identify emerging activities that offer synergies within the objectives of the JRC-ENEA collaboration.

Detailed Status of the JRC/IET-ENEA Collaboration

1. Photovoltaic Solar Electricity Technical Annex

Project Leaders:	**for the JRC: Nigel Taylor** **for the ENEA: Giorgio Graditi**
Title and Short Summary	**Photovoltaic Solar Electricity**
Objectives	**Development of measurement techniques for the electrical and lifetime performance of emerging photovoltaic technologies, including new materials and innovative products for building integration.**

Kick-off meeting 26 September 2012

The meeting was opened by Patrizia Pistochini (PP), who gave an overview of the MoU between the JRC and ENEA. She reported the completion of all technical annexes in the previous agreement, launched in 2008, between the JRC and ENEA. New annexes were added in July 2012 to the agreement, including the review of Annex 01 — Photovoltaic Solar Energy (PSE).

Adinolfi Giovanna, ENEA UTTP-FOTO

PP informed the participants that the responsible person representing the ENEA in the MoU was Gian Piero Celata, and that she had been appointed by Massimo Busuoli, the coordinator of the General MoU JRC-ENEA, to coordinate the relevant technical activities. Giorgio Graditi (GG) is in charge of representing the Technical Unit of the ENEA Portici that will collaborate with Nigel Taylor (NT) of the JRC. Finally, PP said that a full technical report covering the results of the annex was due for publication in the third quarter of 2013. All activities were to be reported to communicate their relevance and impact in the best way.

Raffaele Fucci, ENEA UTTP-FOTO

During the discussion, the contents of the annex were analysed, and the priorities and the staff involved were defined. The comments on single topics were:

Calibration of reference PV cells and irradiation measurement devices: ESTI will continue to provide a calibration service for ENEA reference cells

1 - Solar radiation and spectral measurements, based on intercomparisons (also supporting the Italian National Irradiation Measurement Project)

2 - Completion of the task on Concentrating Photovoltaics (CPV) module power measurement procedures and standards recommendations, by means of inter-laboratory benchmarking

- These activities represent a follow-up from the first annex of collaboration.

Roberto Galleano, JRC-IET

3 - Inter-comparison exercises on the performance measurements of emerging and innovative technologies (organic PV devices, OLED lighting devices)

- Projects should first be defined based on common interest and the availability of infrastructure/laboratories, both at the JRC and ENEA. For areas that chiefly concern the ENEA, Carla Minarini from the NANO unit in Portici will mainly be involved. The JRC will be represented by the Device Calibration group (Harald Muellejans and Giorgio Bardizza).

Giorgio Graditi, ENEA UTTP-FOTO

4 - Development of specifications for an indoor solar simulator for power measurements/calibration of CPV modules

- This is a complex activity and implies the availability of significant human and economic resources. Nigel Taylor and Giorgio Graditi agreed to put this topic on hold.

5 - Common contribution to guidelines for PV modules and system energy performance assessment, including uncertainties

- This point also presents connections and synergy with the Net Zero Energy Building (NZEB) annex. For example, the use of photovoltaics in urban and industrial buildings, for energy efficiency interventions as well as design features, represents a worthy effort for both partners. Alessandra Scognamiglio will be the responsible person for the ENEA.
- Priorities for this activity are to be discussed with the technical responsible persons.

Michele Pellegrino, ENEA UTTP-FOTO

6 - Characterisation procedures for smart PV modules i.e. with integrated maximum power-point tracking and/or storage functions

This is a new activity. The preliminary agreement and definition should be formalised, as well the track to follow.

7 - Definition of electrical, mechanical and thermal requirements for the connectivity of building-integrated photovoltaic products

- This is a new activity. The preliminary agreement and definition should be formalised, as well as the track to follow.

Both parties agreed to strengthen the synergies for the validation of the expertise, the competences and the research activities of both institutions. Some of the activities foreseen

in the present agreement could be the object of a proposal for participation in projects funded by EU Research Framework programmes.
The JRC and ENEA expressed their common interest to optimise the impact of results by producing peer-reviewed publications.

A web-conference for the researchers involved from the JRC and ENEA will be arranged for November 2012.

Video conference

The objective of the meeting is to review progress and define actions related to the specific topics within the PV technical annex.
Details of the proposed actions, schedules and presentations are reported in the sections on individual issues. The responsible persons are also listed.

- **(01) Calibration**

- Tony Sample | Michele Pellegrino — Raffaele Fucci — (ppt 01 ENEA)

This activity has been carried over on a regular schedule since the start of the MoU and can be extended if needed. In the case of reference cells for calibrating thin-film polycrystalline materials, the JRC is also available to provide calibration services. The ESTI, however, does not recommend using thin-film devices (either cells or modules) as reference material. For reference cells, it is better to use suitable filtered monocrystalline devices.

It was agreed that it would be useful to exchange information about the estimation and measurement of uncertainties related to the calibration process. It was also agreed that a pre-audit or check could be of benefit to enable the ENEA to support the preparation of its PVSMART testing laboratory for the official audit of the Italian National Accreditation Body (ACCREDIA). Action: Zaaiman/Pellegrino/Fucci.

- **(03) Solar Radiation**

- Willem Zaaiman, Roberto Galleano | Raffaele Fucci (ppt 03 JRC — ENEA)

Willem Zaaiman,
JRC-IET

Nigel Taylor,
JRC-IET

Alessandra Scognamiglio,
ENEA UTTP-FOTO

Collaboration has been very intensive. Three inter-comparison campaigns were organised: in Portici in 2011 (ENEA), Catania in 2012 (ENEL) and Puertollano (ISFOC) in 2013. The next campaign should take place in May–June 2014 in Madrid (INTA). The JRC and ENEA collaborated actively to disseminate the results and best practice recommendations via an oral presentation at the CPV-8 conference and a paper in the journal *Progress in Photovoltaics*. They also presented at the EU PVSEC in Paris in autumn 2013.

- **(04) CPV Measurements**
- Willem Zaaiman, Matt Norton | Raffaele Fucci - Michele Pellegrino

The JRC is willing to test reference cells Single or Multi-Junction (SJ/MJ if devices are available).

For modules, the JRC is improving its system for measurements of max power under natural sunlight and is interested in introducing an automated alignment procedure. The ENEA has developed this and an exchange of information on this issue is foreseen. Action: Norton/Fucci/Pellegrino.

- **(05) Solar Simulator for CPV modules (*pending)***
- **(06) Energy Performance**
- Robert Kenny | Michele Pellegrino - Felice Apicella (ppt 06 ENEA)

The ENEA presented an overview of its work on the performance of PV systems.

For the JRC, the current focus is on energy rating for modules, linked to the proposed standards IEC 61853-3 (model) and 61853-4 (reference environments) where it is project leader. The ENEA could participate in this process through CEI/CT82.I.

For measurements of energy performance of modules (IEC 61853-1 and -2), there is a common interest in the achievement of a better estimation of the uncertainties. The JRC has several modules that were characterised according to IEC 61853-1 in 2012; a repeat set of matrix measurements by the ENEA could be useful in this respect. Action: Kenny to check module availability.

- **(07) Smart Modules**
- Robert Kenny | Giovanna Adinolfi - Felice Apicella (ppt 07 ENEA)

The ENEA presented its current work on micro-MPPT (maximum power point tracker) electronics. The JRC is interested in modules with micro-inverters, but at present neither organisation has devices available for experimental work in the context of this MoU.

The JRC proposes to initiate the work by focusing on a gap analysis concerning performance standards for such devices. Action: Taylor/Graditi/Adinolfi.

- **(08) BIPV (building-integrated photovoltaics)**

- Heinz Ossenbrink, Hans Bloem | Alessandra Scognamiglio

The responsible people for this task did not participate because the topic overlaps in some areas with activities in the Technical Annex NZEB. A dedicated meeting on this was held in Rome in June 2013.
The third edition of Photovoltaics | Forms | Landscapes will take place in October 2013 during the 28th EU PVSEC in Paris.

- **(02) OLED and OPV (organic photovoltaic)**

- Giorgio Bardizza (ppt 02 JRC) | Maria Grazia Maglione - Pasquale Morvillo (ppt 02 ENEA)

The ENEA presented its work on developing and characterising organic electronics, including OLED and OPV devices. The JRC's efforts in this area started recently and currently target the development of accredited procedures for the calibration of OPV and DSSC (dye-sensitised solar cell) devices. The ENEA expressed its availability to host a visit of JRC staff to its laboratories to share information on performance measurement methodologies. This would provide a basis for defining R&D activities. Action: Maglione/Bardizza.

The JRC noted that OLEDs are currently addressed in its energy-efficiency projects, regarding technology and market outlook of solid-state lighting.

Figure 1.1 - Kick off meeting, from left to right: Patrizia Pistochini, Giorgio Graditi and Nigel Taylor

Mid-term report 3 June 2013

Measurement techniques for new materials, modules and building-integrated products
Main topics:

- Calibration of reference devices;
- International solar radiation and spectral measurement inter-comparisons;
- Setting specifications for solar simulators for concentrator PV devices;
- Pre-standards for the electrical/mechanical/thermal connectivity of building-integrated modules;
- Performance characterisation of 'smart' PV modules;
- Organic devices, organic light-emitting diodes (OLEDs) and uncertainty of energy rating approaches.

Results achieved so far:

- Calibration of ENEA reference PV cells and irradiation measurement devices by the ESTI;
- Contribution to the 2013 international broadband and spectro-radiometer intercomparison at ISFOC (Institute for Concentration Photovoltaics Systems), Puertollano, Spain, where the JRC provides technical coordination. This also forms part of the joint efforts in support of the development of European PV research infrastructure in the SOPHIA coordination activity.

Results

1. Calibration of reference cells;
2. International solar radiation and spectral round-robin;
3. Indoor simulation of concentrated sunlight;
4. Pre-standards for the electrical/mechanical/thermal connectivity of building-integrated modules;
5. Smart PV modules;
6. Organic devices, OLEDs, uncertainty of energy rating;
7. Definition of electrical, mechanical and thermal requirements for the connectivity of building-integrated photovoltaic products.

1. Calibration of reference cells

This activity has taken place regularly since the start of the MoU. The following devices have been calibrated:

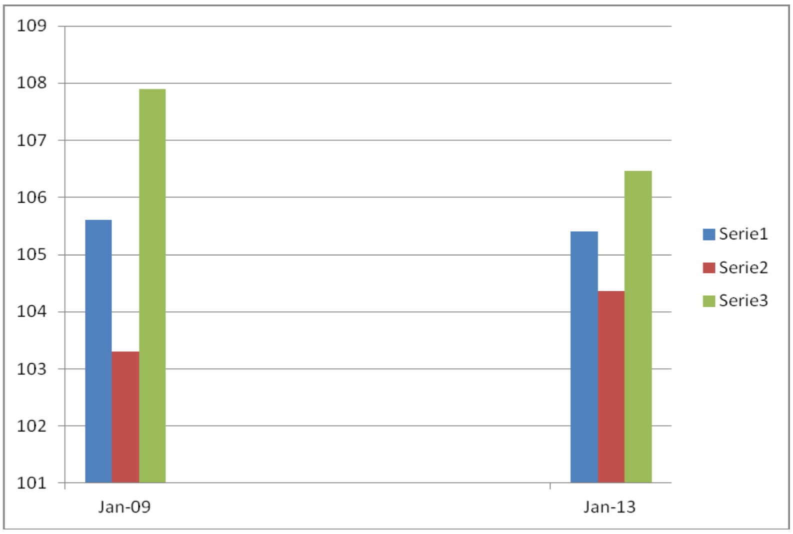
1) Reference polycrystalline Si cell manufactured by Belval, serial number P90 406, ESTI code PK81;
2) Photodiode manufactured by Hamamatsu, serial number S3584-08, ESTI code PK82;
3) Reference monocrystalline Si cell manufactured by Belval, serial number M30503, ESTI code oJ52;
4) Reference monocrystalline Si cell with extra filter glass manufactured by Belval, serial number M30503, ESTI code oJ52;
5) Photovoltaic module with 36 monocrystalline cells manufactured by Eurosolare, serial number D980626, ESTI code oJ51.

<u>Item No 1</u>

- The certificate of calibration for this item was issued on 30 September 2011;
- Calibration method: secondary calibration with reference detector;
- Measurement of photovoltaic current-voltage characteristic complied with IEC60904-1 ed 2 2006-09;
- The short-circuit current at STC, expressed as voltage, was 105.41 mV ± 1.05 mV.

<u>Device history</u>

Date	ESTI code	Ref. Cell	Resp. Factor	Isc (mV)	MMF	Isc_STC (mV)	Uncertainty (mV)
January 2009	AU86	PX201C	123.29	104.41	1.0116	105.60	± 2.3
September 2011	OJ52	PX305C	123.60	105.39	1.0002	119.63	± 1.56



Item No 2

- A record of calibration for this device was issued on 2 February 2013.

Device history

Date	ESTI code	Ref. Cell	Resp. Factor	Isc (mA)	MMF	Isc_STC (mA)	Uncertainty (mV)
February 2013	PK82	NA	1365	176.08	1.0002	176.08	± 1.76

Item No 3

- The certificate of calibration for this device was issued on 30 September 2011
- Calibration method: secondary calibration with reference detector
- Measurement of photovoltaic current-voltage characteristic complied with IEC60904-1 ed 2 2006-09
- The short-circuit current at STC, expressed as voltage, was 105.41 mV ± 1.05 mV.

Device history

Date	ESTI code	Ref. Cell	Resp. Factor	Isc (mV)	MMF	Isc_STC (mV)	Uncertainty (mV)
September 2011	OJ52	PX305C	123.53	118.986	1.0054	119.63	± 1.56

Item No 4

- The certificate of calibration for this device was issued on 30 September 2011;
- Calibration method: secondary calibration with reference detector;
- Measurement of photovoltaic current-voltage characteristic complied with IEC60904-1 ed. 2 2006-09;
- The short-circuit current at STC, expressed as voltage, was 105.41 mV ± 1.05 mV.

Device history

Date	ESTI code	Ref. Cell	Resp. Factor	Isc (mV)	MMF	Isc_stc (mV)	Uncertainty (mV)
September 2011	OJ52_wg	PX305C	123.53	44.155	1.0114	44.66	± 0.58

Item No. 5

- The certificate of calibration for this device was issued on 30 September 2011;
- Calibration method: secondary calibration with reference detector;
- Measurement of photovoltaic current-voltage characteristic complied with IEC60904-1 ed 2 2006-09;
- The short-circuit current at STC, expressed as voltage, was 105.41 mV ± 1.05 mV.

Device history

Date	ESTI code	Ref. Cell	Resp. Factor	MMF	Isc_stc (A)	Voc_STC	FF	PMax_STC (W)
September 2011	OJ51	PX303C	No spectral mismatch correction	1	3.157 ± 0.041	21.21 ± 0.30	70.19 ± 0.51	47.00 ± 0.94

2. International solar radiation and spectral round-robin

Rationale and history

The increasing share of non-crystalline silicon technologies (e.g. thin films) and of III-V compounds in photovoltaics (PV) is placing more and more emphasis on the knowledge and capability of measuring the spectral response of PV devices, together with the spectral contents of the light impinging on such devices. In addition to this, the energy yield estimation/prediction requires, for the specific site under evaluation, the measurement of the solar spectrum variation over days and seasons in order to tailor models to the different PV modules/cells technologies present on the market today.

Spectroradiometers are thus becoming increasingly important tools for laboratories operating in the PV field. While extensive studies and intercomparisons have been conducted for spectroradiometers operating in the ultraviolet (UV) region, only limited work has been conducted on the evaluation of spectroradiometers and their respective measurement/calibration procedures in the wavelength range useful to the PV community. To address this issue, several intercomparison campaigns involving different types of spectroradiometers, covering the wavelength range from 360 nm to 1 700 nm, were designed and performed by JRC, ENEA and several other Italian and European institutions. Three intercomparisons have taken place so far: in 2011 at ENEA Portici (I), in 2012 at ENEL Catania (I) and in 2013 at ISFOC Puertollano (E). Table 1 summarises some key figures about the intercomparison exercise and its evolution over the time.

2011: ENEA, Portici (NA)	First intercomparison, Institutions: 8 (IT, CH and CY), participants: 12, instruments: 20 **ENEA, JRC**, RSE, Uniroma, Eurac, SUPSI, EKO and Unicyprus
2012: ENEL, Catania (CT)	Institutions: 8 (IT, CH, ES, JP), participants: 15, instruments: 30 **ENEA, JRC**, RSE, Uniroma, Eurac, SUPSI, EKO and ENEL
2013: ISFOC, Puertollano (CR), Spain	Institutions: 15 (IT, CH, ES, NL, DE), participants: 22, instruments: 100 **ENEA, JRC**, RSE, ENEL, Uniroma, Eurac, SUPSI, EKO, CENER, INTA, ISFOC, Uni radboud, ISE and 2 groups from UPM

Table 1: Number of institutions, participants and instruments involved in the three intercomparisons of broadband- and spectroradiometers

In addition to the participants reported in Table 1, other institutions from Europe and the US sent broadband radiometers to be measured during the exercise. The increasing number of participants and instruments in use is a key indication of the growing interest shown in this initiative. Figure 1 shows in pictographic form the evolution of the intercomparison in terms of institutions involved and their geographical distribution. The increasing number of institutions and the wider geographical distribution is clearly highlighted.

<u>**Description of the intercomparisons**</u>

Spectroradiometer systems from different manufacturers and using two different technologies (single-stage rotating-grating PD and fast CCD-array spectroradiometers) were set to simultaneously measure global normal incident spectral irradiance (GNI).

Figure 1.2: Institutions and geographical distribution of the participants in the first (lower-left picture) and third (upper-right) broadband- and spectro- radiometer inter-comparisons.

A subset of these instruments was also equipped with proper collimating tubes in order to measure direct normal incident (DNI) spectral irradiance. The covered wavelength range was from 360 nm to 1700 nm. The collimating tubes were designed to have the same nominal field of view (5 °), relative to the instruments' entrance optic. During the intercomparison a variety of atmospheric conditions were experienced. All but one of the instruments involved are fast single-grating spectroradiometers (also known as polychromators) with integration and spectrum acquisition times in the region of 10 ms to 600 ms and with variable idle time between successive acquisitions. The remaining instrument (OL750) is a rotating multi-grating single monochromator spectroradiometer with a full spectrum acquisition time of approximately four minutes. All instruments are equipped with silicon detectors for spectral acquisitions up to 1050 nm to 1100 nm; above this, InGaAS (for the polychromators) or PbS (for the OL750) detectors are used. As entrance optics, the instruments used either diffuser cosine correctors or integrating spheres. Entrance optics were attached to the instruments' bodies either directly or via a fibre optic. Prior to the intercomparison, all participating laboratories calibrated their own instrument(s) according to their usual procedures. The participating laboratories had their instruments calibrated by an external ISO17025 accredited calibration laboratory, performed in-house calibrations using their own radiometric standard lamp(s), previously calibrated by ISO17025 accredited calibration laboratories, or used factory-calibrated spectroradiometers. All participating spectroradiometers were mounted on precision (± 0.1 °) solar trackers to reduce pointing and cosine response errors. A set of reference cavity radiometers, pyrheliometers and pyranometers was also used in parallel during the intercomparison for consistency checks. The JRC-ESTI cavity radiometers gave the intercomparison direct traceability to SI units for irradiance quantity as they routinely take part in the International Pyrheliometer Comparison (IPC) exercise held every five years at PMOD/WRR Davos in Switzerland. Figure 2 a), b) and c) show the instruments set up respectively during the Portici, Catania and Puertollano intercomparisons. It should be noted that the range of instruments involved has widened since the start of the initiative; it now includes ISO-type and reference cells as well as broadband- and spectro-radiometers.

a)

Figure 1.3 a), b), c): various set-ups for the instruments participating in the broadband- and spectro- radiometer intercomparisons. C): Pyrheliometers and spectroradiometers (left-hand side), pyranometers (centre), and iso-type and reference cells (right-hand side).

<u>Issues, challenges and selected results from the intercomparisons</u>

Due to the large difference in the integration and acquisition times among instruments, synchronisation of measurement was necessary to enable further data comparison. A measurement sequence, corresponding to the slowest cavity radiometer measurement cycle, was defined to accommodate several spectroradiometers' measurements.

During the intercomparison campaign, clear- and cloudy-sky conditions were experienced, which allowed for the evaluation of limitations in data comparison from such a range of instrument technologies. Spectra acquired from 'slow' (monochromator) and 'fast' (polychromator) spectroradiometers are influenced differently by varying meteorological conditions. For instance for a polychromator a thin cloud layer passing quickly within the field of view of the instrument may influence only a few spectra within a measurement window, and can be easily eliminated during post-processing. The same condition for a slow spectroradiometer may result in a spectrum distortion in a specific wavelength region and invalidate the measurement in the entire time window.

These factors forced the setting of acceptance criteria for data validation, based on the irradiance stability within the acquisition run. For this purpose, the data from cavity radiometers, pyrheliometers and/or pyranometers, running alongside the intercomparison, were used. Irradiance stability during a defined measurement time window had to be better than 1 % peak-to-peak to flag it as 'stable', and hence useful for further data analysis. This criterion excluded non-clear-sky and fast rising/falling irradiance situations, such as early mornings and late afternoons. Beside the acquisition time, the spectral sensitivity and bandwidth also varies among the spectroradiometers involved in the intercomparison. Therefore, a data reduction (smoothing) function was applied to the acquired data in order to minimise artefacts when comparing results. Figure 3 a) reports a typical solar spectrum acquired during the same time window by the various instruments involved in the intercomparison. The graph (b) in the same figure shows the wavelength-by-wavelength per cent deviation of each spectrum with respect to the Lab A spectrum and normalised to its peak irradiance.

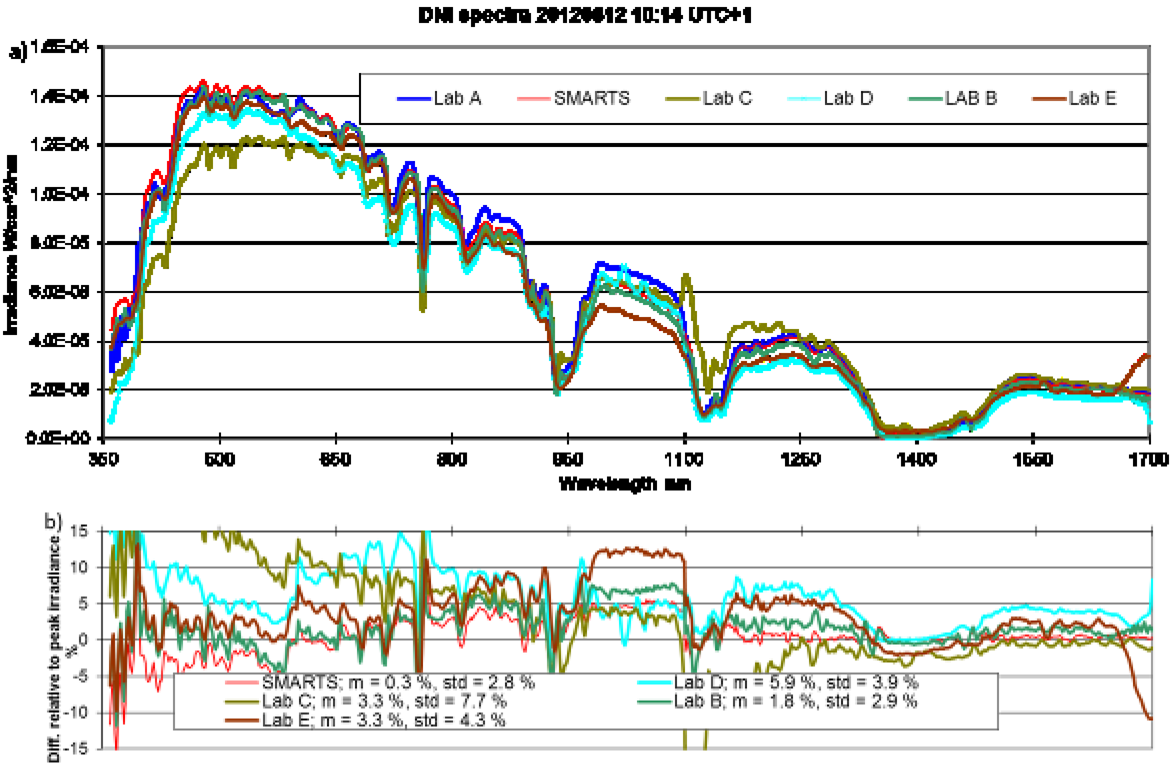


Figure 1.4: **a) Five DNI measured the spectra plus the spectrum obtained during the same time period using SMARTS code. b) Wavelength-by-wavelength difference with respect to the Lab A spectrum and normalised to its peak irradiance; average and standard deviation values calculated over the interval 360 nm to 1700 nm are also reported.**

The average difference values for the measured spectra reported in Figure 3 are all positive and lie in a band of ± 2.1% centred at 3.9% with associated standard deviations of up to 7.7 %. Three systems (Lab B, Lab D and Lab E) have most of their wavelength-by-wavelength difference values lying in a band of -5% to + 15%, while the Lab C data show larger differences. A further analysis on spectra differences was performed by calculating the average spectra mismatch (SMM) values on a set of spectra measured by two instruments in the group for some PV devices using the following equation:

$$SMM = \frac{\int SR_{dut}(\lambda)E_{ESTI}(\lambda)d\lambda}{\int SR_{dut}(\lambda)E_{SUPSI}(\lambda)d\lambda} \frac{\int E_{SUPSI}(\lambda)d\lambda}{\int E_{ESTI}(\lambda)d\lambda} \quad (1)$$

Where: $SR_{dut}(\lambda)$ is the spectral responsivity of each of the considered devices and $E_{ESTI}(\lambda)$, $E_{SUPSI}(\lambda)$ are the spectral irradiances as measured by the JRC and SUPSI spectroradiometers, respectively. The SMM highlights, for a specific device, the difference in using the JRC or SUPSI spectra for calculating the correction to the standard spectrum AM1.5. This parameter is only affected by the spectra shape. The results of the SMM calculations are summarised in Table 2. The SMM values show a lower impact for single-j and wider SR devices and range from 1.017 to 1.047. These results, when applied to an outdoor device calibration exercise where the absolute irradiance value is provided by a cavity radiometer or by a pyrheliometer, highlight that the spectral correction differences may range from 1.7 % to 4.7 %, depending on the considered spectra data set and on the SR of the device under calibration.

Device code	**Technology**	**Average SMM**	**Standard deviation**
NE506 M	InGaP/InGaAs/Ge	1.041	0.005
5_I5 B	Tandem a-Si/c-Si	1.047	0.006
ASP 10	c-Si	1.021	0.002
HR706	CIGSS	1.018	0.002
HR715	CIGSS	1.017	0.002

Table 1.1: Average values for the SMM and its standard deviation as calculated using spectra measured by the ESTI and SUPSI instruments and the spectral responses of devices of different technologies.

Triple junction ISO-type cells were also measured during the second intercomparison in order to evaluate the impact of using different spectra measured at the same time when calibrating the cells. The results of the elaboration of these new data were presented at the 28th EU PVSEC in Paris (October 2013).

5. Smart PV modules

A PV plant is a complex system constituting many electronic and mechanical devices, such as PV modules, converters, tracker systems and optics. It works in continuous changing operating conditions depending on meteorological phenomena (irradiance, ambient temperature) and installation site position (shadow, dust, etc.). The designers' aim is to improve the performance of these systems, increasing efficiency and reliability and reducing costs. Considering, in detail, the efficiency aspect, any photovoltaic (PV) source shows a point of its output V-I characteristic where the delivered power is at its maximum. In order to reach the maximum efficiency, the maximum power point (MPP) has to be tracked continuously, since it continually changes depending on the irradiance level and on the temperature. So, a suitable controller for maximum power point tracking (MPPT) is necessary. When the irradiance level and/or the temperature changes, the MPPT control circuit identifies the direction along which the MPP moves and changes the converter duty-cycle using the right corrections to allow the PV source to operate in the MPP.

In order to make PV generators 'smart', the use of a switching DC-DC converter dedicated to each PV generator (distributed MPP-DMPPT) is commonly adopted to realise MPPT and to adequately link the PV source to loads. In this configuration the power-stage topology plays a significant role in the system's energetic efficiency and cost; the boost is the most commonly used topology, due to its low cost and ease of design. Other topologies can be used, such as the Cuk topology (i.e. buck-boost converter) which assures more flexibility in terms of the value of the output voltage, and allows a better smoothing of the input current. However, it is more complex from the design point of view and is more expensive.

For MPPT control, different strategies and methods are available. Hill-climbing techniques are most often used due to their easy implementation and affordability. They are essentially based on the Perturb and Observe (P&O) method: the operating point is perturbed in a given direction, then the corresponding variation of the power ΔP supplied by the PV generator is monitored. On the base of the ΔP amplitude and sign, the subsequent perturbation of the operating point is decided. The P&O method can be slow and easily 'confused' if the characteristic parameters of the controller are not properly chosen and/or the meteorological conditions rapidly change. To overcome these drawbacks, alternative P&O implementations are proposed: 3-point P&O and variable-perturbation P&O. In addition, other MPPT control techniques are used, based on neural, fuzzy logic or genetic algorithms. Many commercial DMPPT converters are available: Tigo, Sunvision, SolarEdge, etc. However, each is described as working to maximum efficiency without offering any information about the operating conditions in which this performance was achieved.

A unique definition for PV power optimiser efficiency is not available in literature, so it is necessary to fill this regulatory void. The ENEA and JRC are open to working together to develop pre-normative actions to provide a protocol for working conditions and/or measurement procedures relating to the energetic performance characterisation of DMPPT power optimisers.

7. Definition of electrical, mechanical and thermal requirements for the connectivity of building-integrated photovoltaic products (*pre-standards for electrical/mechanical/thermal connectivity of building-integrated modules*)

Most research in recent years into the use of photovoltaics in buildings has focused mainly on *integrating* solar technologies into buildings. This involved concealing solar technologies in familiar shapes so as not to upset people, who often dislike the introduction of new technologies into the landscapes they know. Another key aim has been to avoid consuming additional ground surfaces in a building's physical footprint. However, European (Energy Performance of Buildings Directive: EPBD) and national policies are now pushing for increased use of solar technologies, so that their use is no longer limited at the building scale, but can include the landscape scale.

So, while it is still crucial to design components for buildings, and to assess their performance, there is an emerging need to design solar technologies that will not be directly used in relation to the building (i.e. solar fields). There is also a need to enlarge the design domain from the building to a wider domain that includes the energy-balance boundary.

The use of renewables can be described in terms of *energy generation supply options*, within the project's *physical boundary*. This boundary identifies the project, which is part of the balance consideration, as a single building or a site; it is then drawn at the connection point to the energy supply infrastructure. The physical boundary, within the broader frame of a cluster of buildings implies synergies between several buildings which are not necessarily NetZEBs on their own. The use of renewables needs further investigation in terms of *design options* within a certain spatial domain (this could be the building, the site or the landscape). This spatial domain is determined by the relationships between the renewables (for instance: solar arrays) and the spatial system to which they relate (the building and its site, the landscape).

In particular, the design domain has to be extended to include all the options for generating energy: within the building's footprint (BIPV and BAPV), on site and at site (nearby) and off site. This implies that a nearly zero energy design includes the architectural scale as well as the landscape scale.

Such a condition determines the need for new research, to include in the domain of design for any energy-supply option. Even solar fields should no longer be understood merely as technical systems to generate energy, but also as subjects for design because they have an influence on the landscape, and potentially on culture.

Figure 1.5 — Photovoltaics | Forms | Landscapes 2011: (left) speakers and organisers Walter Hood, Joseph Grima, Alessandra Scognamiglio, Angela Grassi, David Nelson, Heinz Ossenbrink, Mason White and Simone Giostra; round table (right) with Hubert Aulich, Thomas Nordmann, Gianni Silvestrini and Winfried Hoffman

In reply to this new research demand, ENEA and JRC collaborated in the organisation of a thematic event: Photovoltaics | Forms | Landscapes. The first event was staged at the 26th

European Photovoltaic Solar Energy Conference (EU PVSEC) in Hamburg on 6 September 2011, and the second and third respectively at the 27th (Frankfurt) and 28th (Paris) conferences in 2012 and 2013. This annual series serves as a discussion framework that investigates the new phenomena associated with the rapid spread of large photovoltaic systems. It promotes reflection on the implications for our way of living and on what new issues for design could arise. All scales are considered: from modules, to buildings, to cities, to landscapes.

This special event highlights the interaction of PV systems with buildings and landscape. It outlines the vision of a transition from PV architecture into urban and non-urban landscapes and how architects are taking up this challenge. In a future zero-energy-building scenario it is assumed that PV solar energy will cover the energy needs of the living space (electricity services, heating and cooling). But what would these buildings look like when incorporating this energy source? How would out-of-city landscapes offer opportunities to satisfy the demand for energy?

As an official event of the EU PVSEC, the Photovoltaics | Forms | Landscapes workshop is jointly organised by the ENEA, the European Commission JRC, ETA-Florence Renewable Energies and the EU PVSEC. The ENEA is responsible for the conception and programming of the event.

- The 1st edition (2011) addressed the theme: Photovoltaics for Shaping Performative Landscapes;
- The 2nd edition (2012) addressed the theme: How to use Photovoltaics for Shaping Nearly Zero Energy Communities;
- The 3rd edition (2013) addressed the theme: Beauty and Power of Designed Photovoltaics.

The programme of the 2012 edition is included below.

Figure 1.6 – Photovoltaics | Forms | Landscapes 2012: (left) panel with LAGI (Elizabeth Ferry, Robert Monoian), Julian Worrall, Walter Hood, Alessandra Scognamiglio; (right) speakers and organizers Elizabeth Ferry, Robert Monoian, Roberto Zancan, Heinz Ossenbrink, Angela Grassi, Maureen Yap, Chiara Benetti, Julian Worrall, Walter Hood, Alessandra Scognamiglio

Agenda of the 2nd edition of Photovoltaics | Forms | Landscapes

Introduction
Heinz Ossenbrink — European Commission (JRC, Ispra, Italy)
Concept
Alessandra Scognamiglio — Scientific Organiser of the event (ENEA, Portici, Italy)

Presentations
Nikos Fintikakis, Architect — UIA Council Member; Director of the UIA-RES International Work Programme (Athens, Greece)
Global Solar Building Landmarks from a UIA Perspective

Elizabeth Monoian & Robert Ferry — Co-Principals, Land Art Generator Initiative (LAGI) (New York, USA)
The Beauty of Zero Energy: The Aesthetic Integration of Renewable Energy Infrastructure into the Built Environment

Julian Worrall, Associate Professor (Architecture and Urban Studies) — Waseda Institute for Advanced Study, Waseda University (Tokyo, Japan)
Photovoltaics as Public Spaces: Solar Infrastructures in the Post-Fukushima Era

Walter Hood, Director, Hood Design, Oakland; Professor, College of Environmental Design, University of California (Berkeley, USA)
Power Strands

Moderator
Roberto Zancan — Deputy editor, *Domus* (Milan, Italy)

2. Bioenergy Technical Annex

Project Leaders:	**for the JRC: Fabio Monforti-Ferrario/Vincenzo Motola** **for the ENEA: Giacobbe Braccio/Maria Teresa Petrone**
Title and Short Summary	**Biomass potential in Piedmont (Italy)**
Objectives	**Biomass availability and sustainability in the frame of the Renewable Energy Directive**

Objective

The main objective of this activity is to collect data on residual biomass in Piedmont and provide an interpretation of their geographical distribution in the region. This will serve to identify the optimal areas for the location of supply basins and processing plants.

Giacobbe Braccio, ENEA – UTTRI

Summary

Residual biomass is considered a great-value feedstock for bioenergy production. An assessment of its potential is an essential starting point for any local energy planning.

This study aims to give a clear, geographical overview of potentially available residuals in Piedmont and provide a standard methodological and dynamic model for their optimal use. It represents the expression of a collaborative effort between the ENEA and JRC aimed at identifying suitable areas for supply basins and biomass processing facilities.

Vincenzo Motola, JRC-IET

The study is divided into three main tasks. The first one covers the statistical assessment of agriculture and forestry residuals in Piedmont. The second one deals with the construction of a set of geo-referenced data culminating in the creation of availability maps and the application of a multi-criteria analysis aimed at the identification and localisation of optimal supply basins and facilities. Both these tasks are performed by the ENEA. The last task is performed by the JRC and concerns the validation and standardisation of all the methods and procedures mentioned above.

The expected results will be a series of maps (divided by type) on biomass residual availability in Piedmont and a list of the best locations for energy supply basins and facilities.

Kick-off meeting 11 December 2012

Maria Teresa Petrone,
ENEA – UTTRI

Gian Piero Celata welcomed the meeting participants by phone and gave an overview of the scope of the MoU between the JRC and ENEA. He thanked them for their good work in setting up Annex No 03 (Bioenergy) as a follow-up to the previous one. Heinz Ossenbrink thanked everyone for the results achieved in the previous agreement and wished them even greater success in their cooperation over the coming months.

Patrizia Pistochini (PP) explained that all the technical annexes included in the agreement between the JRC and ENEA signed in July 2012 have been started. She said that a technical report describing the results of the annex was expected by next summer (2013).

Giacobbe Braccio (GB) expressed thanks for the invitation to the JRC in Ispra and presented Maria Teresa Petrone, who has been appointed to lead the Geographical Information System (GIS) topic. The other deliverables will be the responsibility of researchers within the ENEA Technical Unit headed by GB.

The subsequent discussion considered the specific deliverables in the annex, including those already reached and those foreseen in the near future.

Specific deliverables for 2012 and beyond

Biomass Atlas

The focus of the common activities in this area has been:

The exchange of working methodologies developed both at the JRC and ENEA.

▪ Organisation of two meetings in Trisaia with the involvement of Vincenzo Motola for the exchange of information and methodologies used by ENEA on data layers;

▪ Assessing the opportunity of extending, at the European scale, the Atlante delle Biomasse in the framework of the SAHYOG project;

▪ Participation of Vincenzo Motola in the progress meeting of the SAHYOG project held in Bruges in May 2012.

1. Progress monitoring of the Italian Renewable Energy Action Plan

Common initiatives have also focused on gaining a better understanding of the sources of biomass energy in Italy, including:

- Evaluation of the current biomass sources available, and implementing a biomass assessment in compliance with the Italian Decreto Interministeriale Luglio 2012 incentives for non-PV renewable power sources;

- Evaluation methods for biomass sustainability, the explicit spatial allocation of biomass sources and Renewable Energy Directive (RED) criteria.

Objectives to be reached

These have been outlined as follows:

- Updating the databases of the Atlante delle Biomasse;

- Extension of the database collection to other sources of biomass for energy use, with a proper reclassification and redefinition of such biomasses;

- Development and implementation of new methodologies and algorithms, scientifically validated at the European level;

- Exchange of experiences and elaboration of databases via researcher exchanges;

- Implementation of the standards required by the INSPIRE Directive;

- Use of Geographical Information System (GIS) techniques to assess the European biomass potential for energy use (in the framework of the SAHYOG project).

Figure 2. 1: Kick-off meeting 11 December 2012 at the JRC, Ispra. From left to right: Giacobbe Braccio, Fabio Monforti-Ferrario, Patrizia Pistochini, Maria Teresa Petrone and Vincenzo Motola

Mid-term report 3 June 2013

1. Developing tools and collecting data to produce atlases of agricultural and forest biomass.
2. Designing biomass environmental indicators.
3. Performing detailed assessments of bioenergy deployment via analysis of NREAPs and other data sources.

Results achieved so far:
1. Common paper on bioenergy potential in Italy.
2. Further development of bioenergy geographical assessment at the European level.
3. Testing the European Pollutant Register as a reliable source for livestock biogas potential.
4. Case study on biomass potential and mobilisation in Piedmont (Italy) in the framework of the HY-TRACTOR project.
5. Assessment of biomass and biowaste resources in Europe in the framework of the SAHYOG project.
6. Case study on forest mobilisation in the Italian Alps for bioenergy purposes.

Future steps:
1. A paper on forestry and agricultural residue harvesting and soil carbon preservation is being prepared.
2. Updating the biomass and biowaste georeferenced inventories in Italy (ENEA Biomass Atlas).

Results

Biomass potential in Piedmont (Italy). Assessment of residual biomass in Piedmont (Italy).

Introduction

The use of residual biomass is expected to make a significant contribution to bioenergy. Therefore, the assessment of its potential is essential as the basis of any regional energy planning. Such assessments can, however, be conducted in several ways, leading to different results. Since different statistical and methodological approaches show different results, finding a standard procedure to follow is of great interest.

This work aims to give a clear, geographical overview of potentially available resources and provide a standard methodological and dynamic model for their optimal use.

It is a collaborative effort between the ENEA and JRC aimed at providing a geographical assessment of residual biomass potential for energy use in Piedmont, and identifying suitable areas to be used as supply basins.

The work is divided into three sections. The first concerns the statistical assessment of agricultural and forestry residues in Piedmont. The second concerns the spatial allocation of the obtained results within the regional territory, and the application of a multi-criteria analysis for the identification of suitable areas for supply basins. Both these activities will be performed by the ENEA.

The third section involves the validation and standardisation of all the methods and procedures mentioned above. This activity will be performed by the JRC.

The work is structured as follows. A statistical study is conducted to gather data on different types of production, which are then analysed and tabled. The methodologies used have been developed by the ENEA-AIGR for the computation of agricultural residues and by the Food and Agricultural Organization (FAO) for the computation of forestry residues (FAO's so-called WISDOM method: wood fuel integrated supply/demand overview mapping). The constructed spreadsheets are then used as input for the ArcGIS software and a multi-criteria analysis is performed to identify suitable supply basins.

The expected results are: 1) the creation of thematic maps on the availability of residual biomass in Piedmont; 2) the identification of optimal supply basins in the vicinity of specific locations (e.g. a farm); 3) the definition of a well-designed procedure that can eventually be replicated in other regions of Italy.

3.1 Statistical assessment of biomass potential

The first step of this work consists in the statistical evaluation of the residual biomass potential available in Piedmont for the purpose of its allocation in the regional territory. Both of these operations require the execution of a series of steps as described below.

3.1.1 Spreadsheets and data acquisition from the ISTAT databases

The Italian National Institute of Statistics (ISTAT) annually publishes and updates 107 databases on agricultural production, with more than 105 crops considered. The statistics are conducted at a provincial level and contain a large amount of information: 600 records for any province. Some of these statistics are used for the construction of our databases that, given the enormity of the provided records, will contain the following appropriate filters and controls.

3.1.2 Spreadsheets and database creation

The census data should be included in appropriate spreadsheets, tailored according to the investigations to be carried out. A spreadsheet is created for agricultural residues and another for forest residues. Both sheets are programmed to perform automatic consistency checks using macros in Visual Basic and generate geo-databases with the developed algorithms. Parameters and collected data are included in the electronic sheets, which also include both agricultural and forestry products.

3.1.3 Agricultural residues

The database of the agricultural residual biomass in Piedmont contains the theoretical quantities of herbaceous and woody biomass expressed in tonnes of dry matter per year, per province. The input data are the ISTAT agriculture acquisitions and the preliminary estimates of residual productivity associated with the main crop.

ISTAT typically estimates annual agricultural land use and production. Therefore, knowledge of the ratio between the main crop and the associated residue is fundamental to defining with reasonable accuracy the amount of agricultural residue per province.

The ENEA-AIGR method allows the user to switch from data on the areas dedicated to the main agricultural crops, published by ISTAT, to an estimation of the quantities of residue left on the field through the use of proper conversion factors.

Biomass is divided into two main categories: ***herbaceous*** (wheat, barley, rice, oats, rye, corn) and ***woody*** (grapes, olives, citrus, peach, apricot, apple, pear, almond, hazelnut, cherry, and nectarine).

Evaluations are based on a computation of the weight of residues starting from statistical data on agricultural production compared and integrated with bibliographic data on the ratio residue/product. The latter can vary according to factors such as crop varieties, cultivation techniques, soil and climate conditions, harvesting techniques and plant pathology. The statistical data are largely derived from the data warehouse available on the ISTAT website (agricultural data) and extracted with a breakdown up to the provincial level.

The resulting geodatabase is designed to manage data relating to the geographical space. It allows the user to view, manipulate and analyse geographically referenced data and to link data to *georeferenced geographic objects* in order to get *smart dynamic maps*. It will immediately give information related to the area in view.

Once the residual biomass quantities in the database have been determined, it is possible to see the geographical distribution on the provincial territory, and to generate interactive thematic maps, query the database with SQL queries and view tables and statistics.

Input data in the spreadsheet

- Product: [main product of the considered crop];
- By-product (SI): [main by-product of the considered crop];
- Production area: [surface area occupied by the crop; ha; input: statistical data; ISTAT];
- Production collection: [weight of the product collected on the surface; t/year; input: statistical data; ISTAT];
- By-product/Product: [ratio between the main product and the associated by-product];
- Humidity S1: [average water content of the main by-product; %].

Output calculation

- Availability of the gross product = [harvested production] x [by-product/product] x [1 - (humidity/100)].

Table 2.1 shows the crops studied and the period of production of the resulting residues.

Cultivation	***Residue***	***Production period***
Wheat	Straw	June–July
Durum wheat	Straw	June–August
Barley	Straw	July–August
Oats	Straw	October–November
Corn	Stalks	October–November
Rice	Pruning	November–February
Grapevines	Pruning	January–April
Apple tree	Pruning	December–February
Pear tree	Pruning	December–February
Peach tree	Pruning	December–February
Almond tree	Pruning	November–December
Citrus	Pruning	February–March
Tree nuts	Pruning	November–December

Table 2.1: Crops and period of production of residues

Following the procedure described above, it is possible to obtain the theoretical potential of residues in Piedmont in tonnes of dry matter per year (Table 2.2).

Provinces	***Straws***	***Pruning***	***Rice husk***	***Shells***	***Grapes***	***Total***
Torino	764,493	5,571	298	54	2,088	772,504
Vercelli	488,597	1,200	122,020	0	179	611,996
Novara	279,259	1,362	54,162	0	461	335,243
Cuneo	474,281	47,018	280	3,967	15,295	540,841
Asti	114,460	29,959	0	1,904	16,475	162,798
Alessandria	303,592	23,839	13,393	143	13,721	354,688
Biella	52,727	1,165	5,340	0	230	59,462
Verbania Cusio Ossola	1,226	98	0	0	25	1,348

Table 2.2: Theoretical potential of residues (tonnes dry matter/year)

3.1.4 Forestry residues

The database of forestry residual biomass in Piedmont, created following the WISDOM method, contains the theoretical quantities of deciduous, coniferous and arboriculture residues. To compute the availability of forestry residues biomass, it is necessary to have knowledge of the following three elements:

1) Annual potential sustainable productivity of biomass for energy purposes

This is the estimated proportion of woody biomass produced annually in the investigated area (i.e. in the forestry district of each province) that is usable in a sustainable way, or within the limits of natural renewability of the resource. It represents an estimate of the woody biomass annually produced in the area of interest, usable in a sustainable way or within the limits of renewability of the resource. Its computation requires the knowledge of two parameters: 1) the extent of forests in the area of interest (by types and prevalent species); 2) the amount of annual growth in the same area.
Starting from these data, and using a few simple assumptions, it is possible to obtain an estimate of the annual potential sustainable productivity in the investigated area (t/year of dry matter).

2) Annual potential sustainable productivity of biomass for energy purposes net of limitations

Not all of the annual potential sustainable productivity can be taken from the forest and transformed into energy. In terms of environmental sustainability, it is appropriate to introduce some restrictions to the withdrawal of biomass. It is also appropriate to consider any limitations on access to the forest. Therefore, the net availability on a territorial scale is less than the potential sustainable productivity in relation to the spatial distribution of forest areas.

3) Biomass consumption for domestic and industrial use

Part of woody biomass annually produced is already used for energy scopes. Unfortunately, the ISTAT databases do not consider information related to such use.

The reasons are many : 1) do not consider the actual consumption of firewood; 2) do not consider the contribution of consumption given by arboriculture and other trees; 3) there are no data on the real consumption of firewood in stoves and fireplaces for private and domestic uses.

The model adopted in this study uses mapping and inventory data to produce geographically detailed estimates of the annual balance between the potential sustainable productivity (net of limitations) of woody biomass and its domestic consumption. This assessment is based on the WISDOM methodology (woodfuel integrated supply/demand overview mapping), developed by the FAO. It was recently applied in Italy for a preliminary estimate of the balance of the demand for, and supply of, wood fuels on a regional scale. One of the key aspects of WISDOM is its flexibility of application at different levels of territorial aggregation (national, regional, provincial, municipal). This makes it an excellent tool for spatial analysis when making georeferenced demand/supply balances.

The estimate of the net annual potentially sustainable productivity of woody biomass for energy use derives from the sum of the potential productivity of wood fuels from different types of forest. This is subsequently reduced when limiting factors such as location and accessibility are taken into account. The classes of forest considered correspond to: 1) sawmills; 2) conifers; 3) arboriculture.

All the information on forest areas is derived from the latest version of the Corine Land Cover (CLC). It consists of an inventory of land cover in 44 classes: 14 of which are deciduous forests, 10 conifers and 3 arboriculture. CLC uses a Minimum Mapping Unit (MMU) of 25 ha for areal phenomena and a minimum width of 100 m for linear phenomena. The time series are complemented by change layers, which highlight changes in land cover with an MMU of 5 ha. The size of the MMU does not allow the capture of information on small plantations not included in forest areas, therefore the quantities of woody biomass actually available are underestimated.

The computation involves the following steps:

1) Each polygon of forest in the CLC is classified by type (deciduous, conifers, etc.) on the basis of data from the Italian National Forest Inventory (INFI);

2) Woody biomass from deciduous trees and conifers are then calculated on the basis of adequate percentages of exploitation (i.e. 30-35 % of the total dendrometric volume for deciduous and 15-20 % for conifers). A biomass expansion factor (BEF) is finally used to get the increase attributable to the total dendrometric volume.

Therefore, an estimate of the annual net potential sustainable productivity can be assigned to each polygon covered by the Corine Land Cover (classified as high forest, depending on the region and the physiognomic class). This is expressed in a range as follows:

Plantations of conifers

Minimum = $I_{C\ INFI}$ * (1-2ES%)*db*BEF*0.15
Maximum = $I_{C\ INFI}$* (1+2ES%)*db*BEF*0.30

Plantations of deciduous trees

Minimum = $I_{C\ INFI}$ * (1-2ES%)*db*BEF*0.30
Maximum = $I_{C\ INFI}$ * (1+2ES%)*db*BEF*0.35

where:

$I_{C\ INFI}$ = current increase in the Italian National Forest Inventory (INFI) for species/groups of species and per administrative region
ES% = standard error on the INFC estimate for species/groups of species at a national level
db = basic density for species/groups of species according to the Italian Environmental Protection Agency (APAT) (now Institute for Environmental Protection and Research (ISPRA)) values
BEF = biomass expansion factor for species/groups of species according to the APAT values

3) The estimate of a coppice's annual potential for sustainable productivity is based on the following assumptions: i) a coppice is trimmed on the basis of the maximum timber production turn physiocratic turn T[1], in correspondence of which the current increase in volume (Ic) is equal to the average (Im); ii) the total area of the coppice in the territorial unit of reference (S), in this case the surface annually used, is equal to s=S/T; iii) under the conditions described above, and assuming use for energy purposes, the entire quantity present in the fraction of usable surface annually, annual potential sustainable productivity of the coppice, based on the surface S can be estimated as:

S/T * T * Im = Ic * S

Also in this case the estimated annual potential productivity is expressed through a range of variation as follows:

Minimum = Ic INFI * (1- 2ES%) * db * BEF
Maximum = Ic INFI * (ES 1 +2%) * db * BEF

The only exception is the chestnut coppice where a fraction of the total availability is aimed at the production of poles: roughly estimated at 50 % of the total volume. Therefore, the range of variation relative to the estimate of annual potential productivity in the chestnut coppice is defined as follows:

Minimum = 0.5 * Ic INFI * (1- 2ES%) * db * BEF
Maximum = 0.5 * Ic * INFI (ES 1 +2%) * db * BEF

As with the high forests, together with the estimate of the range of variation, the value of the average annual potential productivity is calculated.

Following the procedure described above, it is possible to obtain the theoretical potential of accessible forest wood in Piedmont in tonnes of dry matter per year (Table 2.3).

Province	***Hardwoods***	***Conifers***	***Arboriculture***	***Total***
Torino	54,625	724	6,106	61,454
Vercelli	14,414	58	206	14,677
Novara	25,257	225	0	25,482
Cuneo	53,942	838	2,312	57,092
Asti	30,687	44	0	30,731
Alessandria	29,997	415	2,283	32,695
Biella	23,899	81	0	23,980
Verbania Cusio Ossola	9,933	525	0	10,458

Table 2.3: Theoretical potential of accessible forest wood (tonnes dry matter/year)

[1] The entire usable annual growth (associated to the considered area) is available for energy

3.2 GIS-based analysis

The second step of this work involves the spatial allocation of residual biomass in the regional territory, and the multi-criteria analysis aimed at identifying suitable areas for supply basins or energy plants. Both these studies consist of a number of computational steps to be performed with the GIS software ESRI® ArcGIS.

The procedure for spatial allocation will be based on using several spatial layers describing, for example, land cover, expected biomass productivity derived from soil parameters, climatic zones and topographical conditions, etc. Details of this procedure will be given in the next report, together with the characteristics of the geodata layers applied. The maps obtained will immediately give an indication of the most suitable areas for residual biomass exploitation. An example of these maps is given in Figure 2.2.

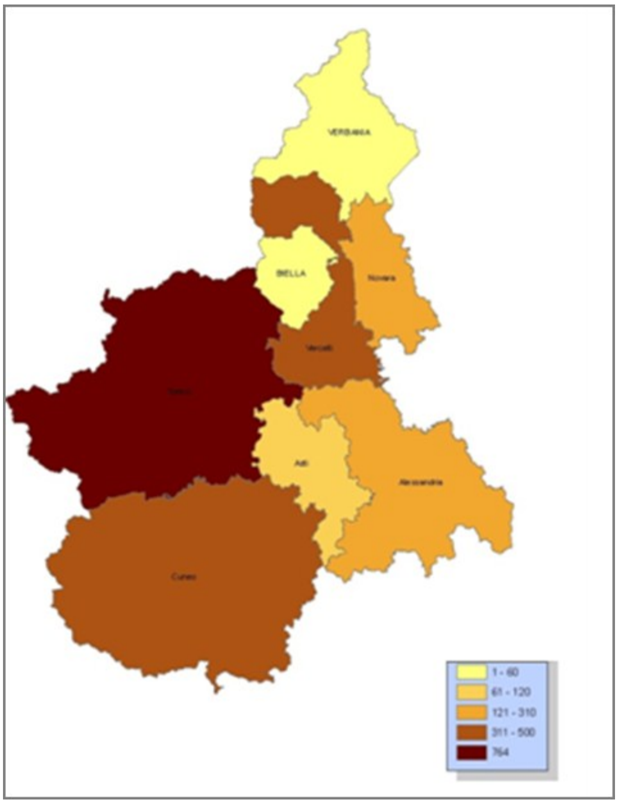


Figure 2.2: Straw Map Piedmont NUTS3[2] Level (Straw tonne d.m.[3]/year)

The multi-criteria analysis is performed by first identifying a series of buffer areas around all the 'best locations' identified for our bioenergy facility. Taking into account potential and

---

scopes.

[2] NUTS Nomenclature of territorial units for statistics - Eurostat

[3] d.m.: dry matter

logistic constraints, the optimal supply basin/s is/are identified. Details on this activity will be also given in the next report, together with the final results.

Cooperation by the JRC–ENEA in the framework of the SAHYOG project

The objective of the Strengthening Networking on Biomass Research and Biowaste Conversion – Biotechnology for Europe India Integration project (SAHYOG) is to actively and effectively link the research activities implemented within EU research programmes and related programmes by Indian national institutions.

The main activities of the SAHYOG project include inventories for biomass and biowaste resources, research projects and programmes, project twinning, short-term exchanges of researchers, summer schools, stakeholder workshops, as well as the development of roadmaps defining key RTD priorities and a Strategic Research Agenda (SRA) to facilitate concerted planning of future EU-India research initiatives in the area of biomass and biowaste.

The main project events with the JRC researchers' contribution:

SAHYOG Expert's meeting on 'EU-India Cooperation on Biomass Production and Biowaste Conversion' Bruges, Belgium, 10 May 2012.

This international meeting between SAHYOG partners and experts from Europe and India organised as a side event of the conference i-SUP 2012 – International Conference on Innovation and Sustainable Production

The aim of this meeting was to discuss the templates being used for data collection for making the SAHYOG inventories of biomass/biowaste production and biomass research projects. Some preliminary results were also presented. This provided an opportunity to improve the methodology, identify missing links and streamline the inventorisation process in India and Europe. Apart from the project partners, experts were invited from European and Indian funding agencies, industries, agriculture producers, logistics, experts from other biomass projects and existing international biomass networks.

SAHYOG Stakeholder Workshop and Project Meeting, Copenhagen, Denmark, 5–7 June 2013

The SAHYOG Stakeholder Workshop 'EU – India Cooperation on Biomass and Biowaste Research and Development' took place on the occasion of the 21st European Biomass Conference and Exhibition. In the stakeholder workshop activities, the findings of the SAHYOG project, specifically the current status of the SAHYOG Strategic Research Agenda, were discussed with international stakeholders. Furthermore, project participants from India presented an overview of current research and development initiatives in the field of biomass and biowaste in India.

First SAHYOG Summer School, 9–16 June 2013, Athens, Greece

The SAHYOG Athens Summer School encompassed a broad range of recent developments on biomass and biowaste conversion routes including the sustainability and LCA of biomass energy for rural development: 20 young Indian and European researchers attended.

Article: Bioenergy production and use in Italy: Recent developments, perspectives and potential. Renewable Energy, Volume 57, September 2013, Pages 48–461, Authors: N. Scarlata, J.F. Dallemanda, V. Motola, F. Monforti.

The paper makes a detailed analysis of the recent developments and expected evolution of the Italian energy mix in the next decade. It provides an overview of the Italian bioenergy sector in comparison with other Renewable Energy Sources (RES) and with leading countries in the European Union with a special focus on production, exploitation and potential on the basis of the analysis of the Italian National Renewable Action Plan.

Statistics among different bioenergy sectors are reported, biofuel and transport, district heating, biogas, pellets, biomass and electricity. The paper also analyses Italian support schemes for biomass electricity production, the incentive's impact on the bioenergy market and future trends.

Conclusions and ongoing work

This report describes the activities done in the course of the first year of collaboration between the ENEA and JRC. Most of these activities took place in regard to the definition of the methodologies and procedures to be followed for the creation of thematic maps on the availability of residual biomass in the Piedmont region and the identification/localisation of the optimal supply basins for biomass processing facilities.

The ENEA has developed a well-defined and standard method for assessing local biomass potentials and creating georeferenced databases. The method uses national statistics on agriculture provided by ISTAT as input data and returns data on residuals on the basis of proper considerations. Moreover, it uses the FAO procedure to supply data on forestry residuals.

The ENEA has also created a series of thematic maps on residual biomass distribution in Piedmont and identified suitable locations for biomass supply and processing facilities. This final part of the study has been performed with the aid of the GIS software ArcGIS® and will be fully described in a further report.

The entire procedure and the results obtained will be tested by the JRC in order to define a consolidated standard method for spatial biomass allocation, and for assessing environmental constraints on the biomass supply chain in accordance with the Renewable Energy Directive (RED).

Publications and conferences

One of the milestones of the ENEA-JRC project will be the publication of technical reports and papers in relevant international journals. Project members also aim to participate in thematic conferences. Both of these objectives will be achieved during the second year of the project.

3. SETIS: Strategic Energy Technologies Information System Technical Annex

Project Leaders:	**for the JRC: Evangelos Tzimas, Christian Thiel** **for the ENEA: Patrizia Pistochini**
Title and Short Summary	**SET-Plan – SETIS 'ENEA Contribution to the SET-Plan – SETIS within MoU JRC-ENEA and Italian SET-Plan Coordination Group Framework**
Objectives	**Mapping of Energy Technology Innovation in Italy within the implementation of the SET-Plan**

Kick-off meeting 14 November 2012

The meeting was introduced by Patrizia Pistochini (PP), who gave an overview of the MoU between the JRC and ENEA and welcomed the participants on behalf of Gian Piero Celata and Heinz Ossenbrink. She explained that all technical annexes included in the previous agreement between JRC and ENEA, launched in 2008, have been completed. Therefore, new annexes have been recently added to the agreement. Annex 4 – SET-Plan/SETIS was updated.

Fabio Monforti-Ferrario has been charged by Heinz Ossenbrink with following the MoU technical activities.

PP informed the participants that Gian Piero Celata is in charge of representing the ENEA within the MoU. She has been charged with coordinating the activities on behalf of Massimo Busuoli, the coordinator of the General MoU JRC- ENEA.

PP said that a technical report describing the results of the annex is expected by next summer.

The new SETIS annex is an update of the previous one, confirming the availability of the ENEA and also of the new Italian SET-Plan Coordination Group Framework represented by Minister Vincenzo Celeste of the Ministry of European Policies, Raffaele Vellone of the Ministry of Research and by Marcello Capra of the Ministry of Economic Development.

Discussion followed on the specific deliverables foreseen in the annex.

Patrizia Pistochini,
ENEA – UTTEI-SISP

Christian Thiel,
JRC – IET

1) Provide an update of the mapping of ongoing projects related to the SET-Plan that are funded by the Italian State and/or its regions; improve the approach to gathering information on projects.

The previous project mapping has been revised and was submitted to the JRC in summer 2012.
Twenty-two projects related to the European Industrial Initiatives (EIIs) have been mapped for a total budget of about EUR 1.8 billion. As to the below table all EIIs are mapped, with exception of solar photovoltaic (PV) and concentrated solar power (CSP); PP and the steering committee followed up on this. No projects are mapped for fuel cells and hydrogen. No representative has been appointed for the remaining EIIs (smart cities and nuclear fusion).

Evangelos Tzimas,
JRC – IET

EII	Number of mapped projects	Budget: million euros
Bioenergy	9 thereof 1CSS and 1 PV	1 626
Carbon Capture and Storage (CCS)	3	1 726
Nuclear Fission	3	23
Electricity Grids	7	15.8
Solar (concentrated solar power: CSP)	0/6 to be mapped	0
Solar (photovoltaic: PV)	1+Bio/4 to be mapped	0.977
Wind	1	6.5
Fuel Cells and Hydrogen (FCH)	0	0
Total	22	1 797

Table 3.1 Projects mapped in Italy

PP informed Evangelos Tzimas (ET) that, due to new validation procedures, she was no longer able to 'generate reports' for the projects mapped. At present she 'uses' a borrowed steering committee password, but it cannot be accepted for private data reasons. ET understands the problem and advises PP to ask the steering committee member to send an e-mail to the SETIS coordinator requesting a password for PP.

PP noted that some projects contribute to two different EIIs and proposed checking if the total budget is not doubled in the two EIIs, and, if not, how it was managed. Perhaps it would be convenient for the compiler to report the relative percentage. For a better understanding, the total budget amount could be written with thousands as separators.

2) Identify and propose the contributions of such projects to the key performance indicators (KPIs) for the EIIs and provide updates on other SETIS activities (organisation of workshops, conferences, etc.).

A SETIS workshop on electricity grids could be considered, as an update to the draft concept for the Mediterranean Area agreed by Efstathios Peteves (EP) and the Italian steering committee of the SET-Plan in December 2010. Some preliminary contacts have already been made by Giovanni De Santi and the Italian steering committee.

PP will investigate with the steering committee and EP, within his hierarchy at the JRC, about the intention of staging a workshop in 2013, as well as its objectives.

CONCEPT to be updated

SET-Plan: An ITALY–SETIS event on electricity grids

What: A high-level event on one of the European Industrial Initiative themes within the SET-Plan.

Concept: A maximum 1.5-2 day event hosted by a Member State that has a strong vested interest and makes a strong contribution to the implementation of the specific technology theme (e.g. Sweden for the Bioenergy Initiative, Austria for the Smart Cities Initiative etc.). The event will be co-organised by the Commission's Strategic Energy Technologies Information System (SETIS) of the SET-Plan and the specific Member State through its representation in the Steering Group of the SET-Plan. It will be organised annually.

Aim: To 'market' the implementation of the SET-Plan by enhancing its dissemination and building a PR profile. To build on the EU added-value and variable geometry ownership by the Member States on the implementation of the SET-Plan

Format: The Conference will include three main sessions aligned to its key goals:

1. An opening high-level political session to demonstrate the support and commitment to the implementation of the Initiative, both on the programme and resource level, and to possibly kick-off a major project and/or a policy measure related to it.
   - Interventions are to be solicited from Ministers, Commissioner(s), Director-Generals from Ministries, the EC, the EIB and other financial institutions.
2. A scientific-technical session that will highlight the programmatic lines of the Initiative and elaborate on the ongoing actions/activities. This session will also underscore the monitoring and review of the progress and the role of SETIS.
   - Interventions are foreseen from R&D leaders from the industries and research community (e.g. EERA, KiC InnoEnergy) involved in the Initiative and from EC officials.
3. A session to underline the ongoing and developing international cooperation that exists around the technology that is the focus of the conference, with the aim of consolidating EU coordination under the SET-Plan.
   - Interventions are foreseen by directors and programme managers related with the EU-US Energy Council, Clean Energy Ministerial, Major Economies Forum on Climate and Energy etc.

The Italian Delegation in the Governance of the SET-Plan and SETIS has preliminarily considered the idea for such a conference and has decided to investigate it further.
The first of such events will be hosted by Italy and will focus on Electricity Networks – the European Electricity Grids Initiative. The anticipated venue for the meeting is Rome and the timing in the period of early July or early September 2011.

The concept of the event once agreed by Italy and SETIS will be presented to the Steering Group for its endorsement

3) Provide data on public RD&D investments in the SET-Plan technologies for Italy in the years 2010 and 2011.

Article 40 of Italian Legislative Decree No 28, March 2011, required the ENEA to report on and monitor energy technologies. The aim is to provide an updated framework and to give an overview of the potential impact of their penetration at local level. The report also evaluates environmental and socioeconomic factors.

The report '*Stato e prospettive di sviluppo delle tecnologie per la produzione di Energia Elettrica, Calore, Biocarburanti e delle tecnologie per l'Efficienza Energetica*'(State and perspectives of technology development for the production of electricity, heat, biofuels and technologies for energy efficiency), will be provided to the Ministry of Economic Development in December 2012. The analysis is at the disposal of the JRC, and the ENEA will forward this report to SETIS once it becomes available.

ET noted that the RD&D investments map will cover not only the public but also the private sector.

Development beyond 2012: assessment of the SET technology-transfer to the eco-industry (green economy)

PP noted the great interest shown by the Italian Ministry of Environment in the green economy during *Ecomondo – Stati Generali*, which took place on 7 and 8 November 2012 in Rimini (Italy) www.statigenerali.org. Seventy proposals were presented for how the development of the green economy could contribute to a resolution of the Italian economic crisis. The development of topics covered by the SET-Plan can contribute to the green economy, but it is essential to define how the technologies are to be transferred.

ET considered the green economy a topic of interest, but said more information on its objectives and implementation would be needed, so that SETIS would have a clearer picture.

ET proposed consideration of ocean-wave power, which is another strategic energy technology in the context of this annex. He asked if the ENEA has expertise in it and, in case of positive feedback, if a collaboration is of interest

Figure 3.1: Kick off meeting, from left to right: Patrizia Pistochini, Fabio Monforti-Ferrario, Evangelos Tzimas

Mid-term report 3 June 2013

Mapping of Energy Technology and Innovation in Italy for the Implementation of the SET-Plan

1. Project mapping update;
2. KPIs for European industrial initiatives;
3. Data analysis of public RD&D investments;
4. Technology transfer, eco-industries/green economy;

Achieved results:
SETIS: 22 projects within the seven European Industrial Initiatives (EIIs) have been mapped in Italy (total budget EUR 1.8 billion)

- Energy Research Knowledge Centre (ERKC): list of Italian energy programmes;
- Italian country overview (under validation);
- Contribution to the report Ocean Energy;
- Sherpa meeting in Brussels: update of SETIS activities;

Next steps:

- Implementation of SETIS and relevant updating activities.

Results

The Italian Coordination Group was established in 2009 to consult with Italian stakeholders and the Steering Group of the SET-Plan supporting SETIS. The collaboration aims at building up a structure to encourage information exchange and data collection and to maintain a database of national projects. The latter includes details related to partnerships and budgets and ongoing or partial results from the projects.

To assist with this work, Patrizia Pistochini was appointed as a national contact point (NCP). She would work closely with SETIS management to optimise data capture at EU level, and to improve the standardisation of different data, while monitoring the status of projects with the Italian coordinators of EII and ERKC.

The Energy Research Knowledge Centre (ERKC) project, developed under the SET-Plan Information System (SETIS) umbrella, was established to help the SET-Plan Steering Group by collecting data on programmes and projects. The aim is to support the appropriate strategy for developing low-carbon energy technologies for 2020 and beyond.

The ERKC enables much greater access to energy research, allowing this knowledge to be exploited in a timely manner across the EU. The Central Unit Studies and Strategies of the ENEA of Italy has been appointed to map some other EU Countries (Spain, Portugal, Greece and Malta) and thereby to encourage further innovation. The unit collaborates within the

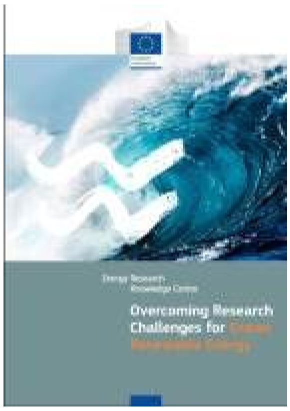
JRC-ENEA MoU and the Italian SET-Plan Coordination Group Framework through the National Contact Point for SETIS (Patrizia Pistochini).

The main energy research programmes in Italy, reported in the country overview, are:

Programme name	Funding organisation	Budget	Time period
Interregional Operational Programme – Renewable Energies and Energy Savings	Ministry of Economic Development (MISE)	EUR 800 m	2007–2013
National Electric System Research	Ministry of Economic Development (MISE)	EUR 600 m	2006–2014
National Operational Programme for Research and Competitiveness	Ministry of Education, Universities and Research (MIUR)	EUR 200 m	2007–2013
Industry 2015 (2009 energy efficiency call)	Ministry of Economic Development (MISE)	EUR 250 m	2006 no fixed end date

Table 3.2 - Main Energy Research Programmes in Italy

An overview of the energy research programmes at national and European level is available in the Energy Research Compendium. This also provides a directory of funding organisations and a synopsis of thematic definitions across all energy technologies:
http://setis.ec.europa.eu/energy-research/content/compendium



As proposed by JRC, another Strategic Energy Technology was included in the Annex: ocean-wave power. A technical expert was identified within the ENEA researchers. He provided the scientific contribution for the editing of a dedicated brochure available on the SETIS website/ERKC project.
http://setis.ec.europa.eu/energy-research/content/policy-brochures

By mandate of the Italian SET-Plan Coordination Group, as expressed by the Ministry of Research, the Ministry of Economic Development and the Ministry of European Cooperation, the National Contact Point (NCP) has coordinated the delegates of the eight European Industrial Initiatives (EIIs) in order to gather specific data on the national projects foreseen by the survey launched by the JRC. The delegates of the CCS, Solar CSP and PV and FCH Initiative are ENEA researchers.

The NCP of SETIS participated in the Sherpa meeting on 11 April 2013 in Brussels, giving an overview of the methodology of the Italian mapping projects and the results achieved. She also explained the difficulties encountered during data entry, the generation of the report and the validation process.

A specific validation procedure has been established by the SETIS staff in relation to the Italian Sherpa and steering committee framework. The total budget of the 22 detailed mapped projects amounts to approximately EUR 1.9 billion. The figures below show details of the projects, per EII, and their budgets and gives an overview of the single countries that participated in the mapping process in the previous edition.

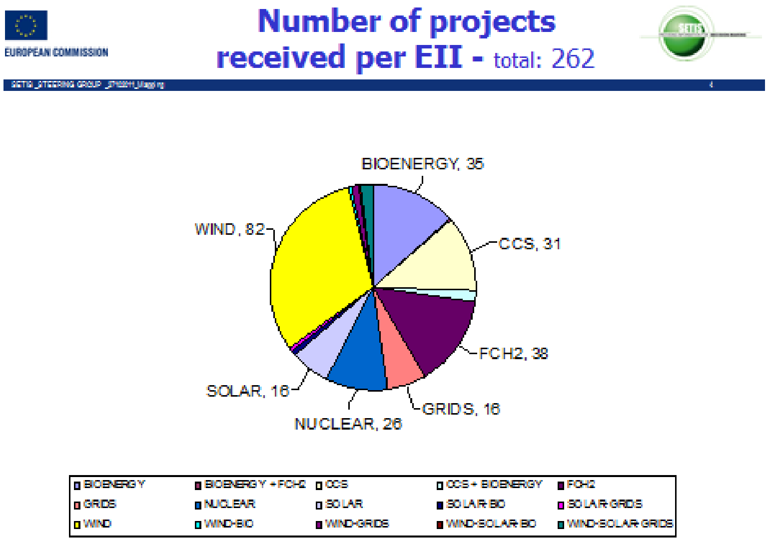


Table 3.2: Number of Projects received per EII

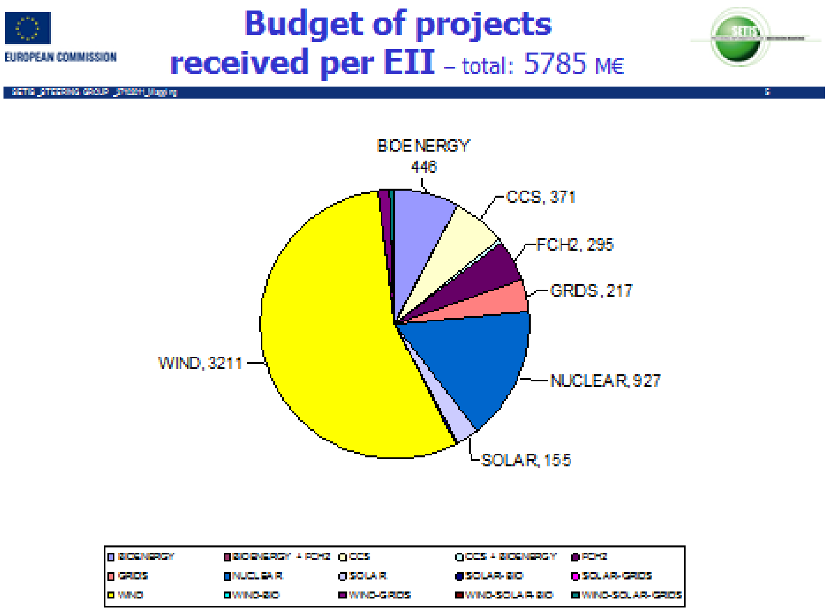
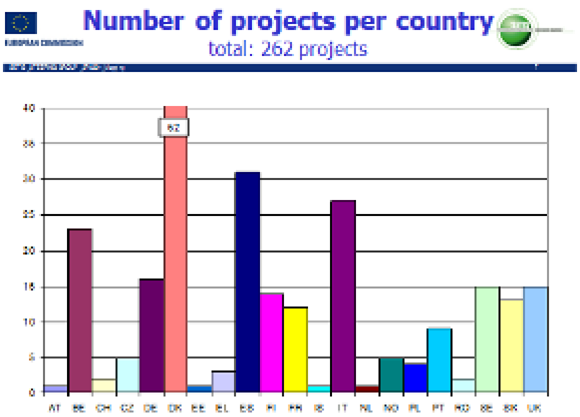


Table 3.3: Budget of projects received per EII



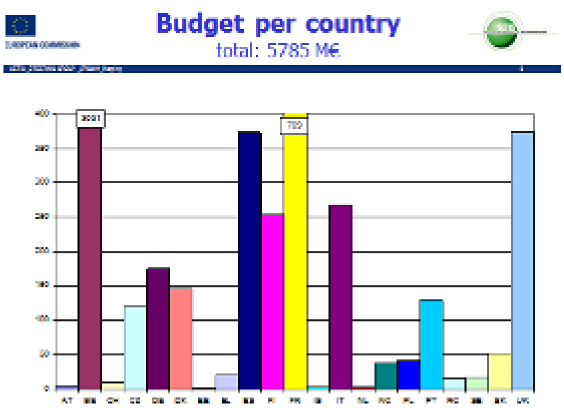


Table 3.4: Number of projects per country **Table 3.5: Budget per country**

The Steering Group has acknowledged the results as the one of best pieces of work provided for SETIS, and has encouraged other countries to follow this practice. Italy has agreed to share its experience with other Member States. This approach should continue within the 2020 Integrated Road Map Agenda of the SET-Plan, which will be defined shortly. The cooperation between the JRC and ENEA was further strengthened by the results achieved and benefits gained in this framework.

On 1 February 2013, the ENEA Brussels was appointed as coordinator of the secretariat of the European Energy Research Alliance (EERA). To date, the EERA has launched 15 joint programmes.

Providing data on public RD&D investments on the SET-Plan technologies for Italy in the years 2010 and 2011.

One of the main outcomes of SETIS is the evaluation of the SET-Plan 2010 Capacities Map, which includes Bioenergy, CCS, FCH, Nuclear Fission, Solar (CSP/PV), Wind and Electricity Grids.

Italy has contributed by providing missing data for 2010 about RD&D Investment in the SET-Plan Technologies, as previously for 2008 and 2009 (Solar CSP/PV, Bioenergy, Wind, CCS, Electricity Grids, Nuclear Fission). The SET-Plan 2013 Capacity map (http://setis.ec.europa.eu/setis-deliverables/capacity-mapping/2013) is downloadable as a Commission Staff Working Document: JRC scientific and Policy Reports R&D Investment in the Technologies of the European Strategic Energy Technology Plan. This accompanies the document COM(2013) 253 final: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Energy Technologies and Innovation; (SWD(2013) 158-157 final).

4. Net Zero Energy Buildings Technical Annex

Project Leaders:	**for the JRC:**	**Paolo Bertoldi/Hans Bloem**
	for the ENEA:	**Alessandra Scognamiglio/Gaetano Fasano**

Kick-off meeting, Rome, 12 September 2012

Alessandra Scognamiglio is already collaborating with the JRC and in September a second edition of the JRC-ENEA workshop 'Photovoltaics, Forms, Landscapes' will take place in Frankfurt at the 26th EU PVSEC. She presented her activities within the IEA Task on behalf of Gaetano Fasano.

The JRC is particularly interested in the contribution of the ENEA experts to the Italian Section of the EU27 heat pumps market report. This survey will include statistics and comparisons with national targets and relevance for NZEBs. The ENEA does not currently have enough man power to support or carry out this activity. However, AC and the Technical Unit 'Heat and cooling system with RES' is participating in an FP7 project which foresees deliverables in this field next year.

The activity of modelling heat pumps, suggested by Biagio di Pietra cannot be included in the agreement with the JRC as this is an experimental activity which doesn't fit into the JRC mission. In fact JRC cannot collaborate in any development activities, except for PV (also referred to as development and e-mobility).

The above topics, referred in Annex 06, are to be cancelled and replaced by new proposals that will be submitted by the Working Group of Ilaria Bertini.

The scope of the collaboration is to present peer-reviewed publications and to participate in European projects and the relative project leaders will act accordingly. The updated proposal will be agreed and presented soon.

Following the kick-off meeting a new technical annex was shared on the reviewed topics.

The ENEA is planning an Italian conference on NZEB as soon as the national regulation is issued (an update draft will be enclosed later in the minutes) with the involvement of the JRC.

AS and HB submitted an abstract to the World Sustainable Energy Days (WSED 2013) – Building Section, High Performance Buildings; A feasible option for the future?, that will take place in Wels (Austria) in next spring.

HB is planning a workshop on NZEB that will take place in Mai 2013 Bruxelles. The ENEA was invited to participate in the organisation.

NEW	ANNEX 06 – Net Zero Energy Buildings (NZEB)
Title and Short Summary	**Net Zero Energy Buildings (NZEB)** Given the global challenges related to climate change, NZEBs are going to be established as a new target in the building sector. The EU Parliament has set an ambitious target on the energy efficiency of buildings that has to be verified by the end of 2018. It is crucial to set in motion research and demonstration activities to promote this target and stimulate the attention of stakeholders. Both partners will share information and experiences within the NZEB sector with EU Member States, as well as making efforts to identify innovative solutions for spreading the application of the technology.
Objectives	**Evaluation of building design regarding energy performance and the integration of solar energy (passive, active and photovoltaics). Investigate how the use of solar technologies (e.g. photovoltaics) for NZEBs will influence the shape of buildings, taking into account different building typologies.**
Specific deliverables/activities for 2012 and beyond	*Survey of best practices related to the design of PV integration, envelope components, integrated façade systems, integrated renewable solutions and architectural design.* Screening of both envelope opaque and transparent systems: vacuum insulation, opaque ventilated facades, cool materials, dynamic windows, phase-change materials and advanced shading systems for the transparent envelope. Screening of the available calculation tools and software for electrical-thermal building demand based on the EU framework standards. The design criteria calculation tools should be based on site and climate, and use passive and photovoltaic solar technologies as part of the building envelope.
The role of the ENEA	Reference Report on NZEB Building Design. Annual Conference JRC-ENEA 'Net Zero Energy Building' (Spring 2013). Organisation of the 2nd edition parallel event Photovoltaics | Forms | Landscapes: How to use Photovoltaics for shaping Nearly Zero Energy Communities (at the 27th EU PVSEC, Frankfurt, 24–28 September 2012).
The role of the JRC	Reference Report on NZEB Building Design. European Conference on NZEB in Brussels (May 2013).
Person-months 2012	JRC: 2 ENEA: 4

Mid-term report 3 June 2013

This is an important topic for improving energy efficiency in buildings and is one of the key requirements of the EPBD (2010/31/EU).

Under the research title, Innovative cost-optimum solutions for NZEBs, two main activities are carried out:

1. Evaluation of building design regarding their energy performance and the integration of solar energy (passive, active and photovoltaics)
2. Investigation of how the use of solar technologies (e.g. photovoltaics) for NZEBs will influence the shape of buildings, taking into account different building typologies (new versus existing, vertical versus horizontal etc.).

Paolo Bertoldi,
JRC – IET

Results achieved so far:

1. Organisation of the 2nd edition of the special event Photovoltaics | Forms | Landscapes, on the occasion of the 27th European Union Photovoltaic Solar Energy Conference (EU PVSEC: Frankfurt, 25 September 2012).
2. Presentation of a joint paper at the NZEB conference in Wels, Austria, 28 February to 1 March 2013.
3. Organisation of an international conference on High-Performance Buildings in Brussels, Belgium, 24 to 26 June 2013.

Future steps:

Summary paper on NZEBs for publication in a journal

1. Organisation of the 3rd edition of the special event Photovoltaics | Forms | Landscapes, on the occasion of the 28th EU PVSEC (Paris, September 2013).
2. Common work on NEZB definitions, including consultation with stakeholders.
3. Establishment of evaluation criteria that accord with the Energy Performance of Buildings Directive (EPBD) and comparative methodology guidelines.

Hans Bloem,
JRC – IET

Alessandra Scognamiglio,
ENEA – UTTP-FOTO

Results

Two main results have been achieved through the collaboration between the JRC and ENEA on Net Zero Energy Buildings (Annex 06):

1. Joint presentation at the World Sustainable Energy Days – Nearly Zero Energy Buildings conference in Wels, Austria, 28 February–1 March 2013 (Hans Bloem, Alessandra Scognamiglio: High-performance buildings. A feasible option for future cities?).

2. Joint organisation (JRC – ENEA – INIVE/DYNASTEE) of an international conference on High-Performance Buildings in Brussels, 24-26 June 2013, during European Sustainable Energy Week (EUSEW) 2013.

At the design and evaluation methodologies workshop staged in Brussels under Point 2 above, the ENEA was mainly involved in the organisation of Session 4: 'High-performance building design: solution sets, case studies, processes, open issues'. This reflected its involvement in the IEA SHC[4] Task 40-EBC Annex 52 Towards Net Zero Solar Energy Solar Buildings, and, in particular, in Sub-task C: Advanced Building Design, Technologies and Engineering. The ENEA also supported the event by publicising it (and the related call for papers) on its website.

Persons involved:

- Alessandra Scognamiglio (UTTP-FOTO): Session 4 chairperson;
- Valerio Abbadessa (UCREL-BRUX): welcome from the ENEA;
- Gaetano Fasano (UTEE-ERT): presentation on The Challenge to Reach the NZEB in Italy;
- Sonia Pirozzi (UCREL-PROM): promotion of the event through the ENEA website.

The papers and presentations from the workshop are available on the JRC website:
http://iet.jrc.ec.europa.eu/energyefficiency/workshop/workshop-high-performance-buildings-design-and-evaluation-methodologies

A short summary follows of the main issues that emerged from the event and in particular Session 4. These can be considered as possible new research issues for NZEBs.

Figure 4.1: TVZEB (Traverso Vighy Zero Energy Building) prototype for an NZEB, Vicenza, Italy, 2013. Design: Traverso Vighy (www.tvzeb.org)

[4] International Energy Agency – Solar Heating and Cooling – Energy in Buildings and Communities.

High-performance building design: solution sets, case studies, processes and open issues

The EU Sustainable Energy Week (EUSEW) is an initiative of the European Commission. It is coordinated by the Executive Agency for Competitiveness and Innovation, in close cooperation with the European Commission's Directorate-General for Energy. It showcases activities dedicated to energy performance, efficiency and renewable energy solutions. During that week, INIVE-DYNASTEE[5], EC-JRC-IET and the ENEA organised a series of four half-day workshops on the theme: High-Performance Buildings – Design and Evaluation Methodologies. The workshops were held in Brussels at the offices of the Belgian Building Research Institute (BBRI) from 24 to 26 June 2013. About 125 experts from around the world registered for the workshop.

The aim of the event was to focus on the energy-related element of the design process for new or renovation buildings. It was organised in four consecutive sessions dealing with dynamic aspects of performance assessment, including cost analysis, monitoring, evaluation and modelling of high-energy-performance buildings, variable aspects such as renewable energies and consumer behaviour, design case studies and CEN[6] energy standards related to the Energy Performance of Buildings Directive (EPBD: 2010/31/EU). Experts from CEN TC371, working on the revision of the standards, were invited to participate, as were project leaders from IEA-EBC Annex 52 (NZEB), Annex 53 (Monitoring) and Annex 58 (Performance characterisation).
The definition of Nearly Zero Energy Buildings is one of the hot topics in many recent papers, and articles and principles for NZEB are presented. The presentations highlight the status and requirements on monitoring, modelling, evaluation and demonstration of building energy performance assessment.

For the implementation of Directive 2010/31/EU on the Energy Performance of Buildings (recast EPBD), it is essential that the design process takes into account the energy flows, in particular from passive solar and landscape design (orientation and immediate environment, including soil) integrated with architectural design. This design will have to incorporate technologies that are related to the envelope (ambient exposed surface area) and space (volume contained by the envelope). In addition, information and communication technology is expected to play an important role in the optimisation of distributed energy supply and demand.

EU Member States have to develop definitions and roadmaps for the implementation of NZEB buildings. Implementation would be a giant leap forwards in the development of a sustainable energy future for our built environment. Therefore, it is important to assess the real performance of construction projects, and to try to fill the gap between the real (measured) performance and the anticipated performance. Calculation of the latter is based on models and assumptions. Several research projects are focusing on this challenge.

[5] INIVE is the International Network for Information on Ventilation and Energy. DYNASTEE stands for: DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of buildings.
[6] CEN is the European Committee for Standardisation.

Of particular note in the area of standardisation activities are the new EN standards. These are currently being developed under mandate M480 and designed so that they can be used as a reference to demonstrate compliance with the legal requirements given by Member States according to Directive 2010/31/EU on the Energy Performance of Buildings (recast EPBD). This specifies qualitatively the concept of the 'Nearly' Zero Energy Building, underlining the requirements for high-energy performance and a major fraction of energy generation from renewable sources. An unambiguous assessment procedure is required to determine the energy performance that is required so that fair and transparent Energy Performance Certificates (EPC) can be issued which can be checked against legal requirements.

Studies on the monitoring of NZEBs, and verification from the IEA Task 40/Annex 52, were also presented. A basis for future standardisation should be created by harmonising definitions and by developing tools, innovative solutions and guidelines related to NZEB.

An important issue in the overall energy balance of a dwelling is the level of comfort it provides for occupants. On this point, there has been discussion of the level at which the occupants' behaviour plays a crucial role in the final energy consumption calculation that indicates a building's energy performance. It should be noted that *passive buildings with active occupants are more efficient than active buildings with passive occupants*[7]. However, the question remains how to assess the passive design element of the building-performance calculation.

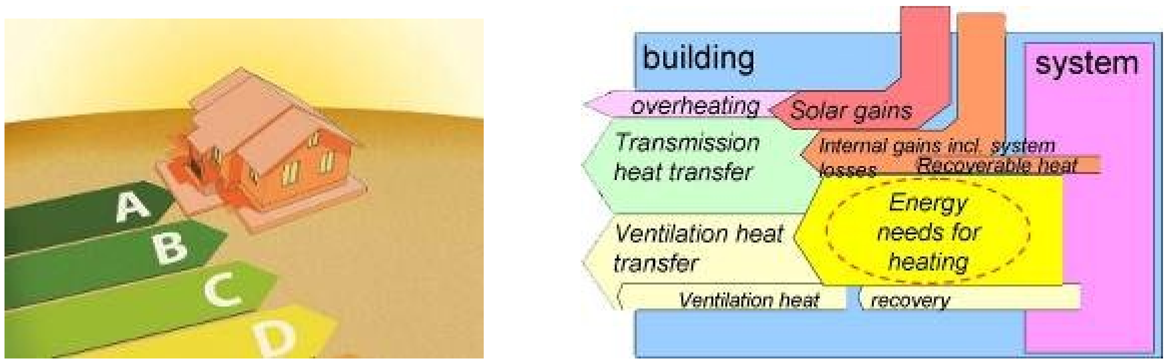


Figure 4.2: Main issues of Net Zero Energy Building

There are several problems in calculating the energy requirements for high-performance buildings (such as low-energy, passive, NZEB or smart buildings). These range from lack of consensus among Member States around definitions for such buildings to the calculation for applied conversion techniques to Primary Energy definitions. The question can be posed:

[7] François Garde, How to design a Net Zero Energy Building? Solution sets and case studies: experience and feedback of the IEA Task40/Annex52, paper presented on the occasion of the workshop on High-Performance Buildings - Design and evaluation methodologies, Brussels, 24–26 June 2013, p. 4.

how reliable are present simulation methods in predicting the primary and final energy consumption?

Issues arising

The exchange of information and knowledge at this type of event enriches and encourages continuous collaboration and the sharing of new insights. The organisers intentionally invited people from a range of different disciplines (building research, architects, academic, experts from standardisation bodies) to ensure a broad-based discussion of topics related to high-performance buildings and energy.

The practical and generic aspects of monitoring and data analysis were discussed. Examples were given of the work needed to pave the way for building-energy monitoring and standardisation applications that deliver genuine value.

Discussions related to CEN standardisation activities confirmed the need for clear definitions and national options. Representatives of CEN clarified how to specify national options without disrupting the common EN standardised calculation framework.

It was concluded from several presentations in Session 1 that there is not a unique and well-established understanding of NZEB. Many NZEB concepts were based on this exchange with the infrastructure, and especially with the electricity grid. It would help greatly if there was to be more communication between these complementary areas of expertise, like performance testing, monitoring, standards developers and building simulation experts. This would lead to an improved exchange between standardised methods of calculation and techniques for measuring and evaluation.

When a building is not monitored and optimised in the operation phase, it is widely observed that a gap occurs between simulated and measured data i.e. energy consumption is higher than anticipated in the operation phase. This can be due to the bad performance of the energy systems used in the building, or to the users' behaviour.

Main results from the Session 4 discussion

A high-performance building is designed to use all possible passive strategies to reduce energy consumption within the envelope. It is constructed of low-energy materials and uses the most efficient systems to reduce energy consumption. When possible, it incorporates energy-generation technologies into its physical footprint.

To facilitate the design and construction of high-performance, low-energy buildings, there is a need for more simulation of what this entails and for monitoring and optimisation of the process. In addition, the systems and performance of buildings should be continually monitored after completion to ensure their energy performance meets expectations. This is also key to understanding how user behaviour affects performance.

A net zero energy building is a complex system with many sub-systems, and it is not currently possible to model the whole performance of a building using only one simulation code. Combining different simulation tools is not easy, even for experienced users. If the performance of a single system is easy to predict, its performance when coupled with another system is much more unpredictable. Consequently, further research is needed in this field to provide designers with easy-to-use methods and tools for designing high-performance buildings.

One possible way to support designers is to use a simplified approach that considers which solution sets can be used in a building. These will depend on its function (residential/non-residential), the climate, and the main challenge this creates (heating, cooling or heating and cooling).

The continuous improvement of envelope technologies is leading to a ‘super-insulated envelope’ that might create cooling problems, even in countries that are heating dominated. Therefore, in order to keep energy consumption low, it is necessary to design buildings so that natural ventilation can be used to reduce energy consumption.

Despite a considerable ongoing technology research effort, some experiences in hot climates demonstrate that a simple approach is the best. In particular, very simple design rules, and the use of simple technologies, can ensure a good building energy performance. Experience in hot climates demonstrates that interaction of the envelope with the outdoor space is very important. This contrasts with the notion that a compact and insulated envelope is required.

Some guide concepts have emerged from experience in hot climates. For example: the shape of the building should be elongated so as to enhance natural ventilation; and sun-shading should prevent the building from overheating. The comfort of the occupants can be greatly improved just by using simple systems such as ceiling fans.

The ideal shape of a high-performance building (for example with large surfaces where photovoltaic modules can be installed) contrasts with the shape of buildings in very dense cities around the world. This condition implies the necessity of re-thinking the idea of the city itself, so that it can include the surfaces necessary to house the energy-generating systems a city requires for energy self-sufficiency.

Possible future research issues

1. High-performance buildings and interaction with the users (comfort and cultural preferences)

A view emerged, from some participants in the discussion, of buildings as complex precision machines, whose predicted behaviour is sometimes ‘disturbed’ by the behaviour of their users. From this point of view, users adapt the buildings to their needs. These are mainly related to comfort, but also to cultural factors.

The approach to creating new energy-efficient buildings is traditionally rooted in the engineering discipline. As a result, the architectural and spatial qualities of the building (which can take into account cultural factors related to the users) often becomes secondary. A possible consequence of this approach is that, although energy-efficient, the buildings that result are not fully ‘in tune’ with the cultural preferences of the users. It seems that the design process should integrate both engineering and architectural aspects (in addition to economic) to ensure both energy efficiency and user satisfaction.

2. High performance design in the case of ‘average’ buildings (especially residential ones)
For certain building categories (i.e. the residential ones that we can observe in peripheral cities areas) often the design process is not necessarily driven by energy objectives. Moreover, a design approach that privileges economic goals, together with a need for an easy realisation, imply a low level of technology (materials, systems, techniques) used in the building. This results in buildings that do not perform very well in terms of energy behaviour. Even for these categories of building (where the cost are kept low, and the technology used is low-performing) it is necessary to develop an appropriate design process, together with a post-commissioning process, that should be easily accepted by developers and users.

3. The Nearly Zero Energy objective at the community scale
It is no longer appropriate to confine energy efficiency to single buildings. If a building has an insufficient surface area for installation of active solar components, then the scale of the energy balance should be extended for instance by considering other renewable resources (such as bi-valent heat pumps), or by installing renewable generators off-site. This would suggest an enlargement of perspective from nearly zero energy buildings to nearly zero energy communities. From this point of view, a smart energy grid will be key to the success of the project. The size of the grid should define the scale of the domain in which to achieve the zero-energy balance: building envelope, building ground area (including open surfaces, neighbourhood, district, community, town or city).

The energy balance of such an extended domain should be considered as the result of a certain number of buildings as a whole. Even when individual buildings cannot make use of on-site renewables, there is a strong argument for extending the domain to include them; for example, by renovating old buildings.

4. Zero Energy Buildings in developing countries: what design process? What maintenance protocol? What to use in the absence of a reliable energy grid?
Cities in developing countries represent a crucial issue, because it is predicted that most of the world’s population will, in future, be concentrated in them. This poses new questions, such as: is it possible to create high-performance buildings with a simplified design process? Is it possible to conceive a workable protocol for their maintenance (post-commissioning phase) that users can manage themselves? How will such buildings perform in the absence of a reliable energy grid?

Reference

HIGH PERFORMANCE BUILDINGS – Design and Evaluation Methodologies. Summary report – Authors: Bloem, H., Bacher, P., Scognamiglio, A., Socal, L., Strachan, P., Vandaele, L.

5. E-Mobility Technical Annex

Project Leaders:	**for the JRC: Harald Scholz** **for the ENEA: Antonino Genovese**
Title and Short Summary	**Electromobility**
Objectives	**Testing Methodologies/Batteries/ICT/ITS systems: sharing of the experience gained**

Kick-off meeting 12 September 2012

This section represents the conclusion of a previous exchange of mails and a visit by the ENEA to the Vehicle Emissions Laboratory (VELA) of the JRC at Ispra. The energy efficiency potential of electric vehicles (EVs) is greater than that of conventional ones; hybrid vehicles (HEV) represent a technology bridge. The JRC VELA performs tests on conventional vehicles, while those of the JRC Petten contain the EU reference laboratory for fuel cells.

Antonino Genovese,
ENEA — UTTEI-VEBIM

Harald Scholz (HS) explained the activities started on electromobility and why it appears attractive. At present, the test methodologies and procedures are adapted from conventional vehicles to EVs but they are not made for them. International efforts (involving JRC) have started at CEN/CENELEC and UN-ECE level, and elsewhere, to address the issues of BEVs (Battery Electric Vehicle), HEVs (Hybrid Electric Vehicle) and PHEVs (Plug-in Hybrid Electric Vehicle). The JRC has started to work on recharging time, range tests and energy recuperation efficiency during deceleration. Data have been exchanged with other European projects and groups on, for example, fuel cell vehicles discussed at UN-ECE level. HS showed how the Integrated European EV/Smart grid Reference laboratory (under construction in 2013 and 2014) will operate, and stressed the importance of interoperability. Gian Piero Celata (GPC) confirmed the profitable integration of EVs and smart grids. HS concluded the intervention by listing the pre-normative activities performed.

Giorgio Martini,
JRC – IET

Antonino Genovese (AG) and Giovanni Pede (GP) presented the different methods used to test the energy and environmental performance of electric vehicles and the importance of defining a standard testing methodology. Procedures for testing hybrid vehicles were also explained with regards to the effect of control strategies and Charge Sustaining (CS) and Charge Depleting (CD) operations. The presentation was followed by an analysis of the specific activities of the ENEA against the objectives of the annex:

- Testing Methodologies: for electric and hybrid vehicles;
- Batteries: storage systems for electric vehicles;
- ICT/ITS system: the on-board system (OBS) for charging management.

The collaboration agreement between the JRC and ENEA aims at defining new cycles and tests and their implementation, but also at testing batteries, as confirmed by Heinz Ossenbrink (HO).

Harald Scholz,
JRC – IET

Both parties confirmed their availability to train the respective personnel.

AG and GP, together with HS, have agreed to write a paper to be published in an international scientific journal.

Figure 5.1: Intense technical discussions at the first Rome-based ENEA-JRC meeting identified synergies to harvest by cooperation. From left: Heinz Ossenbrink, Gian Piero Celata, Harald Scholz, Giovanni Pede, Alessandra Scognamiglio, Antonino Genovese, Heinz Ossenbrink, Gian Piero Celata, Hans Bloem, Andrea Calabrese, Biagio Di Pietra, Giovanni Pede, Alessandra Scognamiglio

Mid-term report 3 June 2013

Test methodologies for the energy and environmental performance of electric vehicles (EVs)

1. Evaluation and classification of e-vehicles, focus on energy and environmental efficiency;
2. Comparison of energy storage systems;
3. Assessment of information communication technology (ICT) systems for the charging/grid interface.

Achieved results:

- Testing of batteries' performance under extreme conditions;
- Provision and starting up of a research-grade battery cycler designed for research on Li-ion batteries and super-capacitors. An AVL cycler is designed for high-power and high-speed performance in order to test batteries in common conditions and in non-usual stressed conditions;
- Provision of a climatic chamber for extreme environmental testing of Li-ion -cells and modules:
- Provision of apparatus for x-ray computer-tomography of EV-batteries at the JRC, Petten.

Evaluation of electric vehicles

- Common identification of a test matrix of 5/6 EVs for testing energy efficiency, consumption, etc.;
- Acquisition of an electric Nissan Leaf car for testing on a roller bench. This ENEA vehicle is available to be used also in the context of a cross test with the JRC Ispra VELA-2 labs (-15 °C to 45 °C);
- First tests of typical urban, small EVs (*Smart Electric Drive* and *Renault Twizy*) undertaken at the JRC, Ispra, based on new European driving cycles (NEDCs) and Green e-Motion drive cycles. The new worldwide harmonised light vehicles test procedure (WLTP) drive cycle is anticipated in 2013.

ICT system for the charging/grid interface

- Modelling of private mobility using real data collected on a large scale with GPS on-board devices (Florence and Rome, Octo Telematics data of March 2008 and May 2010, respectively);
- Analysis and quantitative evaluation of private mobility needs and potential EV-energy consumption using real data collected on a large scale with GPS on-board devices (Florence and Modena, Octo Telematics data of May 2011).

Next steps:

1. Tests on more EVs with a different test cycle (WLTP) and under heating, ventilation and air conditioning (HVAC) use conditions;
2. Tests of abnormal use of Li-ion cell batteries in cooperation with the EC Petten Lab (computer tomography analysis);
3. Electric vehicle behaviour in the urban context with grid-load evaluation from energy-charging consumption;
4. Identification of testable EVs – grid communication devices/systems from European manufacturers (also in view of comparison and interoperability with US solutions).

The ENEA is involved in the *Ricerca del Sistema Elettrico* (RDS), which is a national programme providing R&D. It aims to encourage innovation in the Italian national electricity system; enhance the system's reliability and service quality; reduce its impact on heath and the environment; and rationalise the use of energy sources. The research projects are implemented under programme agreements between the Italian Ministry of Economic Development and ENEA, the National Research Council (CNR) and Ricerca sul Sistema Elettrico (RSE S.p.A.). To date, the projects of the second year of the 2012–14 programme agreement are under way.

Today, many car manufacturers are already producing and selling electric vehicles that display interesting performance in terms of autonomy and energy consumption. However, we need to overcome two barriers to a more substantial insertion of electric vehicles into the market. The first concerns financial issues, such as overall vehicle price and costs associated with battery-maintenance and battery life. The second is the 'anxiety range' caused to the driver of the electric vehicle by the reduced autonomy in comparison with a conventional vehicle. There are two ways to overcome the second point: improve the capacity of energy storage and implement fast-charging technologies. A suitable network of charging stations operating in fast-recharging mode connected to the electric grid is a viable solution to sustain the diffusion of electric vehicles. Fast charging can be implemented by 'electric refuelling stations' operating in very fast-charging mode (about 10 minutes) or in public areas (intermodal parking, shopping centre parking) where electric vehicles are parked long enough to recharge the batteries in a normally fast-charging mode (about 30 minutes).

The use of lithium batteries for electric traction has been a step-change that makes road transport electrification potentially more marketable, notably in urban areas. Lithium-ion batteries are complex and integrated systems of electrochemical and electronics, able to provide high-energy recharge/discharge cycle efficiency and the high current rate necessary to develop rapid charging. Lithium-ion batteries are already used in recharge operations at a rate of 1.5–2 C, and battery manufacturers are researching how to operate them at a rate of 3C. It is also necessary to develop a quick-charging system to support the fast-charge operation and thus to decrease the charging time of electric vehicles.

There is also the option of using electric vehicles without fast charging. In this scenario, slow-charging technologies connect the vehicle to the home electrical socket (e.g. overnight). Commercially available electric vehicles are already equipped with this option, and no further actions are required for the free use of them.

A study of the interrelationships between the electrical system and urban mobility was carried out to highlight the daily distance driven by private vehicles, and to check the condition of autonomy necessary for electric vehicles in urban areas. As a result of this 'private-mobility' analysis, we calculated the amount of power to be delivered by the electric grid when electric vehicles are charging in the slow-charging mode. We also performed an analysis of urban mobility, using a large sample of monitored conventional vehicles, equipped with electronic data loggers.

A second experimental analysis was carried out to verify the fast-charge operation, and in order to evaluate the power conversion efficiency and the impact on the electricity grid. In order to perform this test, a fast-charger station with CHAdeMO[8] protocol was used to charge a Nissan Leaf electric vehicle.

Mobility analysis using data recorded on board urban private cars for electric-vehicle charging strategies

GPS systems are popular in the vehicular research environment because they can provide detailed information on the daily use of a vehicle, and on the weekly or monthly frequency of use. This information is useful to better understand how the vehicles are used in terms of distance covered and time spent travelling. We can collect information about the maximum daily range and provide a scheme to replace Internal Combustion Engine (ICE) vehicles with electric vehicles. Data analysis was carried out on the data available for a whole month for a substantial number of vehicles in the province of Rome. The first analysis was made to evaluate what is the longest daily route and to verify the percentage of vehicles that would travel only with the night-charging operation guaranteed. The analysis was repeated assuming that all vehicles analysed would be circulating as electric vehicles, and that these would belong to one of six size-classes divided according to battery capacity. Then the analysis simulated the battery charging, according to four different charging profiles, and checked the effect of these charging profiles on travel range. The results are shown by highlighting the percentage, by class, of ICE vehicles that could be transformed into electric ones. Finally from these data, we calculated the electricity network load as it developed over 24 hours.

Data were collected by Octo Telematics Co. using GPS devices (black boxes) mounted on many vehicles (classified as 'conventional' for insurance purposes). The data were gathered during a whole month over a large geographical zone that contains the whole of the municipality of Rome.

[8] CHAdeMO is an abbreviation of *CHArge de MOve*, equivalent to 'charge for moving' (see: http://chademo.com/06_What_is_CHAdeMO.html).

Figure 5.2*: The rectangular geographic area of trips analysis data provided by Octo Telematics. The red dots represent the homes of 33 193 'resident's vehicles' inside Rome's Grande Raccordo Anulare (GRA) Ringroad.*

We used the available data to assess how many internal combustion engine vehicles (ICEV), in their daily use, do not exceed the range of an EV. This identifies the number of vehicles that are already eligible to be substituted by an EV without having to change their daily usage when adopting home recharging. It is also considered an analysis that, in addition to home recharging, includes '*more than one charging away from home'.* This was to verify if the number of vehicles converted to EV would increase. This study considers six different classes of EV, from the cheapest electric quadricycle to the more expensive SUVs.

The samples were collected throughout May 2011 within a rectangle of about 129 x 98 km^2 that contains the whole province of Rome. The database, containing 106.98 million records, was subject to a preliminary analysis to remove the anomalies due to inconsistent and interrupted recordings. Thereafter the place of residence was determined based on the most frequent overnight parking location.

The revised database contains information about 116 700 different vehicles of which 80 961 belong to residents in the monitored area. These represent 2.66 % of all vehicles registered inside the area; 48 400 vehicles are present inside the municipality of Rome (2.54 % of all those registered). However, in order to have a more homogeneous sample, we only considered resident vehicles inside the *Grande Raccordo Anulare (GRA),* the ring road that surrounds the city. Hence, 33 193 is the final number of vehicles in the sample, which are represented by red dots in Figure 1. Of these 33 193 vehicles, we selected only those 13 399 that never left the monitored area. This was defined as the Reference Sample (RS) to be used in the study.

Our present study has adopted the six size-classes of EV that were reported in two JRC publications by E. Paffumi et al. and M. De Gennaro et al. reported in the references. These are shown in detail in Table 5.1. Columns 2 to 4 show the weight, power and battery capacity for each class of vehicle.

Vehicle Class	Weight [kg]	Power [kW]	Battery Capacity [Wh]	Electricity Consumption [Wh/km] ([km/kWh])	Range [km]
Light quadricycle	450	13	13	70 (14.3)	186
Small-size car	1.080	47	16	186 (5.4)	86
Medium-size car	1.521	80	24	210 (4.8)	114
Medium-size car	1.815	125	32	205 (4.9)	156
Large-size car	2.108	310	85	236 (4.2)	360
Large-size SUV	2.600	300	85	265 (3.8)	321

Table 5.1: List of classes of EV in column 1. Weight, power and battery capacity, in columns 2 to 4. In the last 2 columns: consumption, derived from the test drive and autonomy

The last two columns show the electricity consumption, based on a test drive, and the autonomy of the vehicle. To avoid damaging the battery, we used between 20 % and 95 % of its nominal capacity, because the state of charge (SOC) between these two values is handled automatically so as to be invisible to the driver. The advantage of this collaborative approach with the JRC Electric Vehicle Interoperability Assessment Centre (EVIAC) project was the comparability of our results with the results from the team at the JRC in Ispra. This developed similar analyses of Octo Telematics' data for the areas of Florence and Modena.

To assess the number of ICEVs that could be converted to EVs using only the home recharge, we identified the most critical day of the month for each vehicle, corresponding to its maximum daily distance travelled. Therefore, the analysis of a single day, for each vehicle, is sufficient to identify vehicles that are able to circulate in electric mode on each day of the month. The result is reported in the green curve in Figure 2, which represents the cumulative number of vehicles, with the maximum daily distance travelled.

The green line shows that, during the month of our monitoring data, 46.5 % of the vehicles did not travel more than 86 km per day, which corresponds to the range of a 'small-size EV' in Table 5.1. It also demonstrates that 93.4 % of vehicles always travel a maximum distance below the range of 186 km, which is the autonomy of an electric quadricycle.

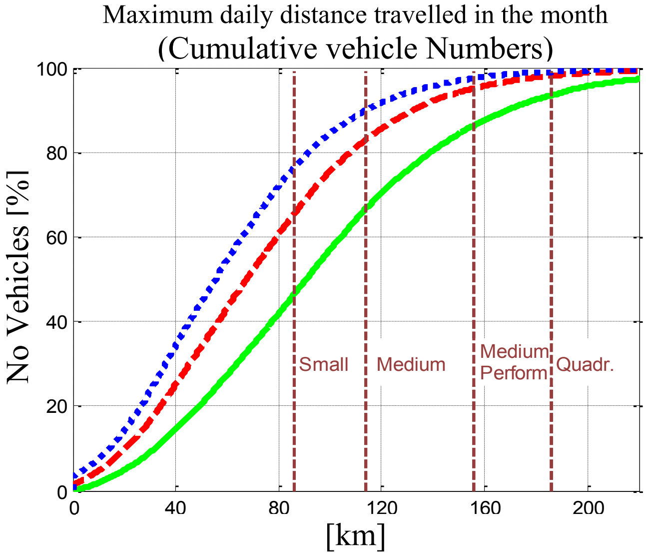


Figure 5.3: Maximum daily distance travelled in the month (Cumulative vehicle numbers)

The green curve shows the cumulative number of vehicles, of the RS, that never exceed a certain daily distance. The same result, excluding for each vehicle the day with maximum mileage, is shown by the red curve. The blue curve result excludes two days with maximum mileage. The vertical lines represent the autonomy of the various classes of electric vehicles.

During a month, users might have to drive for more kilometres than is permitted by a certain EV. In these cases it is assumed that, once or twice a month, users can drive another owned or hired conventional vehicle or use another transportation mode. Therefore, the dashed red curve in Figure ***5.3***: Maximum daily distance travelled in the month (Cumulative vehicle numbers) always represents the second-longest distance travelled in the monitored month, while the dotted blue curve represents the third-longest distance. The histogram of Figure 3 shows the percentage of vehicles *possibly* converted to electric, for each class.

If we analyse the periods when each monitored vehicle is non-operational, it is possible to perform a recharging operation when these exceed a reasonable minimum. Figure 4 shows a distribution of frequency of non-operational periods as a function of the initial time of the cars being switched off, and also grouped as per the duration of non-operation. During the day many vehicles are non-operational for a long time (from four to eight hours) and during this period they can be recharged. For this study we assumed that such recharging can take place anywhere, as long as the duration of the stop is appropriate. Battery charging is simulated according to four different durations of charging, in order to verify the possible electrification of individual transport without altering the trip distances observed. If, even for a single day, the battery is not able to power the daily routes completely, the vehicle cannot be converted to an EV.

In Figure 5, the percentage of vehicles that could be converted is grouped by possible charging duration. On the right the percentage of kilometres possibly travelled by EVs is shown. Battery charging is simulated according to four different charging times.

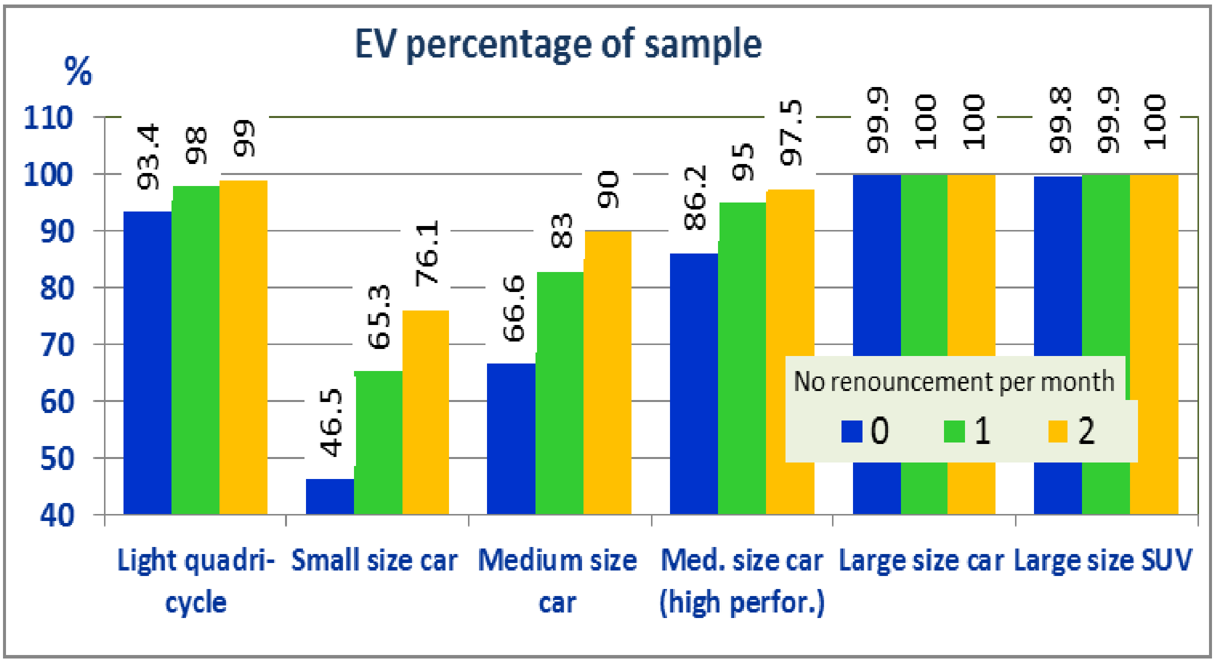


Figure 5.4: Percentages of EVs that can circulate without intermediate reloading.

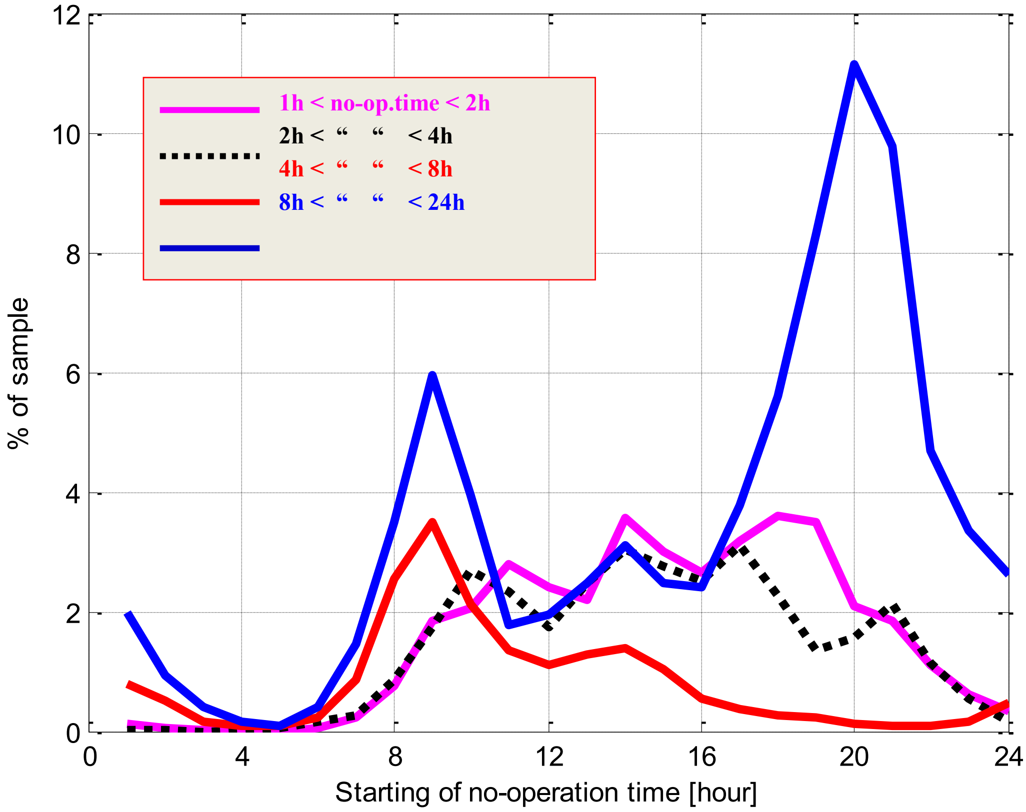


Figure 5.5: Distribution of no-operation events versus starting no-operation time.

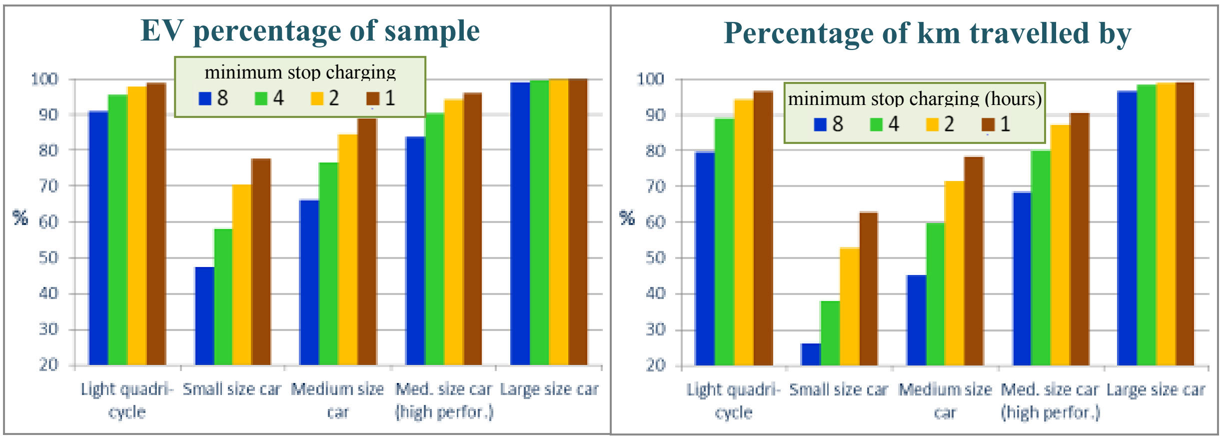


Figure 5.6: The left histogram, in the function of the recharging time in the legend, shows the percentage of 'EV-convertible' vehicles in our sample, for each class of EV. The right histogram shows the percentage of km travelled by the 'converted' (i.e. EVs), compared to those of the whole (conventional) sample for each size-class of EV.

Load on the electricity grid

From the information available on the possible recharging periods in the observed (conventional) car use, it is possible to extract the load on the grid distributed over 24 hours if the conversion to EVs was undertaken. The power load for recharging, for eight hours non-operational stops and for one-hour non-operational, is shown in Figure 5.7**Figure 5.7**.

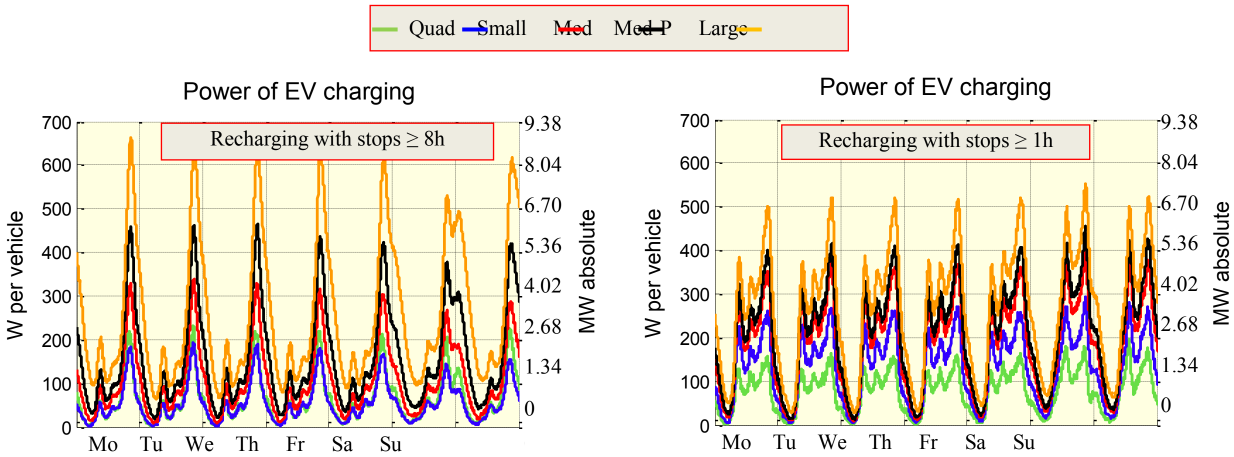


Figure 5.7: In the first week of May 2011, for five classes of EV in the legend, the resulting power load to recharge the EV is shown

On the right, the 'Small' EVs have higher power consumption in comparison with the eight-hour charging operation. This is due to the fact that recharging during a one-hour stop increases the number of EVs connected to the grid, as also shown in the left histogram in Figure 6. Moreover, in this case the mileage travelled for each vehicle is increased. This can be deduced from the right histogram of Figure 6, where the increased percentage of travelled km (for one-hour stop) is more accentuated than the percentage increase of vehicles.

The same graph also shows a high power load for 'Large' EVs compared to other classes of vehicles. This is due both to their higher energy consumption and to greater distances travelled. The decreases in power peaks on the right graph for 'Large' EVs is due to more frequent, but more moderate, recharges, which lead to a better energy distribution.

Power distribution from the 'Small' EV on a working day is shown in Figure 5.8Figure 5.8. It highlights that, for a recharge on an eight-hour stop, the power peaks in the evening; for a recharge on a one-hour stop it follows the traffic trend.

The energy taken from the grid (area under the curve) during a one-hour recharge (red curve) is greater than the other charging modes for two reasons: the increased mileage of the vehicles and the greater number of vehicles converted to EV.

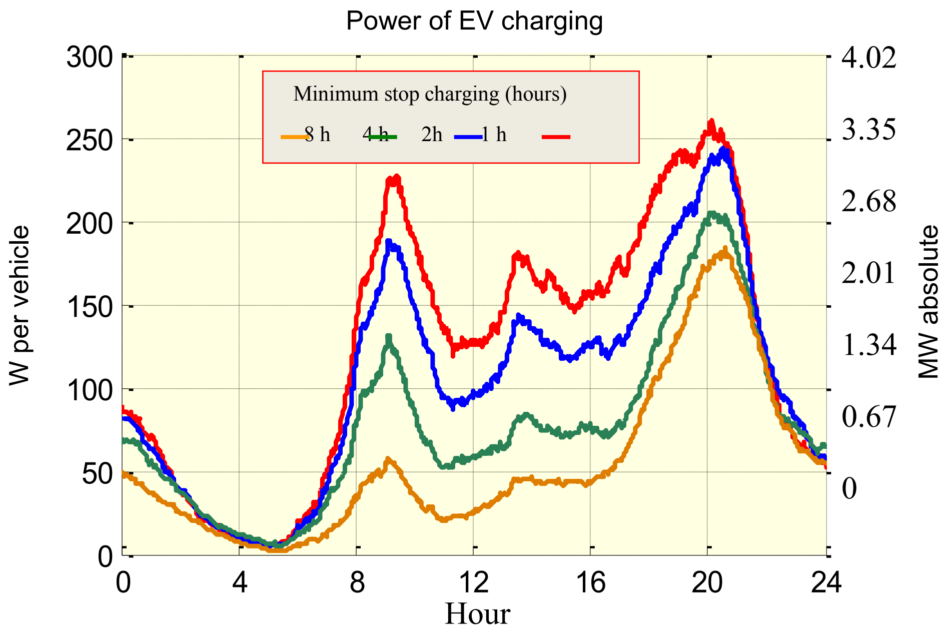


Figure 5.8: Travelled distance per hour of a 'Small' EV resulting from analysis of the reference sample.

.

Fast-charge analysis

The challenge of an EV is to match the recharge 'performance' of the conventional vehicles. The few minutes required to refuel a petrol or diesel car represents a fantastic goal that appears for now to be unreachable. Reductions in recharging times will inevitably be connected to widespread installation of fast-charging stations. These stations are characterised by supplying a power of several tens of kWs and being connected to the low-voltage grid. Generally the fast-charging stations are of DC type (direct current) interfacing the storage system according to mode 4 of IEC 61851. In this way the charger is located off vehicle, powered by the AC grid, and the power connection with the vehicle is in DC. The charging control is operated by a vehicle-station communication link by means of a suitable communication protocol. One of the standards currently on the market is the CHAdeMO, which allows a maximum of 62.5 kW DC power (500 V @ 125 A). This standard originated in Japan, and has so far been followed by the Nissan-Renault alliance. It has also found wide acceptance with other Japanese manufacturers. For instance, the models Nissan Leaf, Mitsubishi i-MiEV, Citroen C-Zero and Peugeot iOn are equipped with charging systems based on CHAdeMO. Other models, like the BMW i3 or the VW eUp, feature the COMBO-plug system, downward compatible to the Type-2 plug system for AC charging. The CHAdeMO protocol provides communication via a controller area network (CAN) bus, which provides the proper support to the control actions during recharge.

Fast-charging is predicated on the availability of a powerful AC grid connection at low voltage. The connection of large loads to the grid from fast stations could lead to a degradation of power-grid quality by the effects of the non-linearity of the AC/DC conversion system. This power quality degradation becomes more perceivable when there is more than one charging stations along the same line.

We evaluated both the effects on the electric grid and the performance in terms of power quality and energy efficiency. In coordination with a static compensator, we assessed the power requirement of our fast-charging device versus the grid, in order to check how the compensation strategy of the power drawn from the grid can help to reduce the line voltage drop during the fast-charge operation.

Figures 8 and 9 illustrate the electrical performance of a fast-charging station under test. For the fast-charge assessment, a Nissan Leaf test car was used, which is equipped for the CHAdeMO plug-type and charging protocol. Fast charging is divided into two phases: first a constant current charge and second a constant voltage charge. Maximum DC power was 50 kW, with a maximum current of 125 A entering the battery pack. When the battery voltage reached 400 V, the constant voltage charge started until the battery SOC was at 90 %. In this phase, the energy charged by the battery pack was 13.5 kWh. The conversion efficiency of fast-charger station was evaluated to be 92 % at high output power, but the efficiency profile shows the efficiency decreased at lower output power.

The measured current distortion was high because the first stage of AC/DC converter in our charging station is a bridge rectifier, and the current is strongly distorted by the non-linearity. We had to place a filter on this stage to reduce the percentage of total harmonic distortion (THD) and the current levels of harmonic components.

A static converter was coupled with our charging station in order to have an integrated charging station. Such a static converter is a device that can give active or reactive power to the grid in order to decrease the power request at the MV/LV transformer upstream. A static compensator is an electronic bi-directional inverter that has a DC bus connected with a Li-ion battery pack or another DC source. When the power demand on the AC line increases over a fixed threshold, it reacts providing active power directly on site. This action reduces the power to be provided by the electric transformer and, therefore, the static compensator acts as a peak-shaving device. Figure 5.11 shows the peak power at initial charging required by our fast-charging station (55 kW) to produce a step in the power transformer output, but this is compensated by the active power generated by the static compensator. Then the transformer power decreases until the power at the fast-charge station is below a threshold voltage.

Figure 5.9: A fast-charging station with static compensator and a Nissan Leaf EV.

Figure 5.10: Nissan Leaf connected to a fast-charging station.

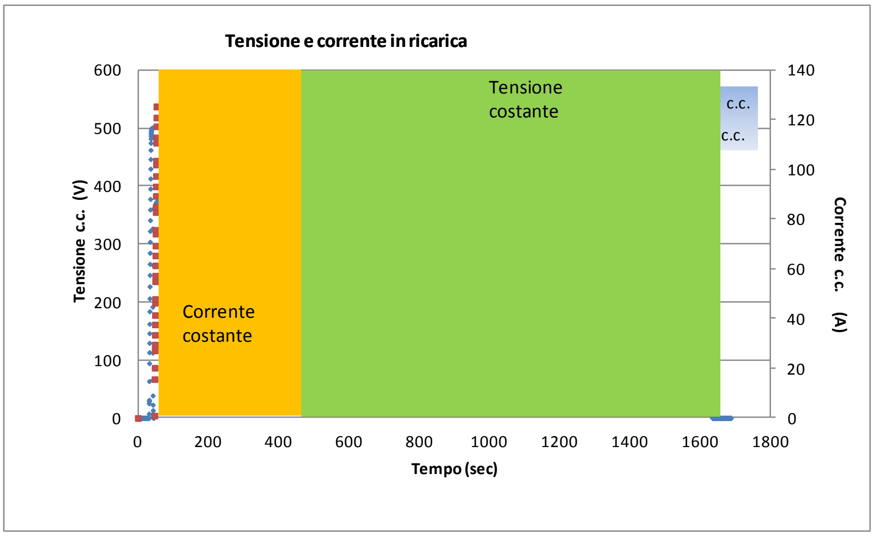


Figure 5.11: DC voltage and current versus time during the fast-charge operation.

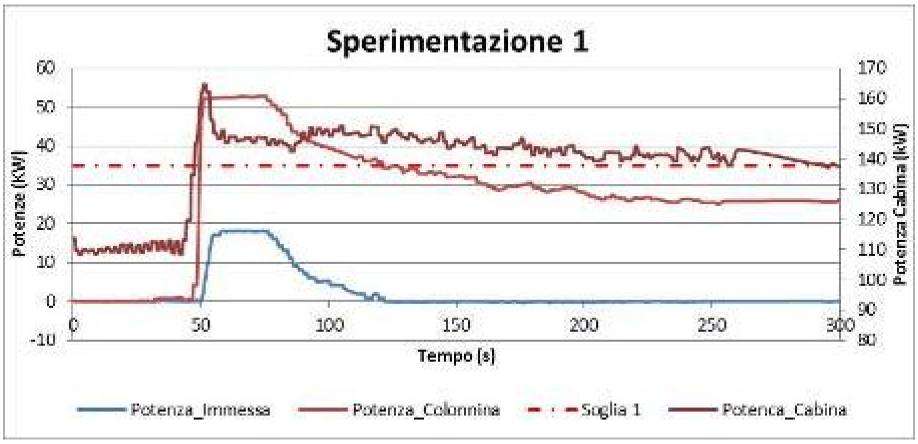


Figure 5.12: AC power profile with static compensator.

Results

The ENEA mobility analysis was performed using a common classification of the electric vehicles to comply with the JRC ongoing studies. As previously described, very interesting results have been achieved by both partner institutions regarding the Octo Telematics GPS-based mobility data. These represent the reality of individual vehicle traffic in the typical European cities of Rome, Florence and Modena. As the next step, a benchmarking paper will be jointly authored, underpinning the highly interesting results of both partners. This will compare the ENEA results for Rome with those of the JRC's EVIAC project team for Florence and Modena.

A staff member of the ENEA electric vehicles lab has visited the JRC laboratories to assist at a specific test campaign on a Mitsubishi eMieV electric vehicle, and get to know the Ispra testing team and the parameterised dense programme of test-cycles (NEDC-, WLTP-, MAC-cycles at varied temperature levels). One of the results of these tests was, *inter alia*, the importance of electricity consumption for passenger cabin heating and cooling, and the measurement strategies for quantifying energy recuperation during braking.

At the end of 2013, the ENEA will provide its Nissan Leaf EV for a week of detailed testing at the JRC's roller-bench facility at the VELA in Ispra. This will contribute to the ongoing, systematic collection of data on many electric vehicles (for the EU market and in view of the transatlantic cooperation between the JRC and the Argonne National Laboratory).

The theoretical work and direct exchange of practical, technological testing experience in 2013 has benefited our cooperation, collegial friendship and common capacity. In future, both our institutions expect to undertake a lot of pre-normative work, and have already conceived ideas for further cooperation. In this context, the advances of the ENEA in the impact of fast charging on the grid are highly interesting to JRC Ispra, while their car-testing facilities, existing and under construction, (VELA-8 cold chamber, VELA-9 EMC testing chamber) open up more possibilities for future fruitful collaboration.

Future actions

1) Reverse battery charge for fast charging: testing of a compact electric converter;
2) Comparison between DC and AC fast-charge stations (also receiving results from the JRC);
3) Nissan Leaf testing: on-road versus test bench (in full collaboration with the JRC, Ispra).

References

Genovese, A., Ortenzi, F., Di Pietra, B., Sbordone, D. '*Realizzazione e sperimentazione di una stazione di ricarica rapida in c.c. nel C.R. Casaccia*'. Report RdS/2013/135 *Rapporto tecnico Ricerca del sistema elettrico*, September 2013.

Giuli, G., Mancini, M., Valentini, M. '*Studio delle interrelazioni tra il sistema elettrico e quello dei trasporti urbani*'. Report RdS/2013/133 *Rapporto tecnico Ricerca del sistema elettrico*, September 2013.

Paffumi, E., De Gennaro, M., Scholz, H., Martini, G. 'Electric vehicles and charging strategies to meet urban mobility requirements'. *WIT Transactions on the Built Environment* 130, pp. 533–544, 2013.

De Gennaro, M., Paffumi, E., Scholz, H., Martini, G. 'Analysis and assessment of the electrification of urban road transportation based on real-life mobility data'. 27th Electric Vehicles Symposium, Barcelona (Spain), 2013.

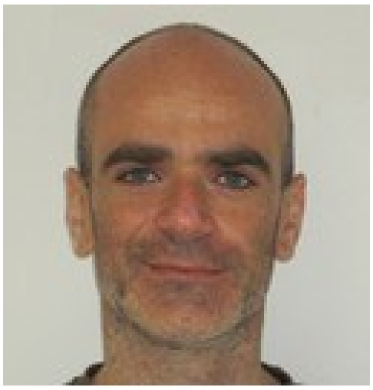
6. Mapping of Wind Resources Technical Annex

Project Leaders:	**for the JRC: Fabio Monforti-Ferrario/Thomas Huld** **for the ENEA: Massimo D'Isidoro/Lina Vital**
Title and Short Summary	**Assessing wind and sun potential complementarity in Italy**
Objectives	**Developing, applying and evaluating a methodology to assess wind energy potential**

Kick-off meeting 19 October 2012

The meeting was introduced by Patrizia Pistochini (PP), who gave an overview of the MoU between the JRC and ENEA. She explained that all technical annexes included in the previous agreement between JRC and ENEA, launched in 2008, have been completed. Therefore, new annexes were added to the agreement in July 2012, including the present Annex 09 – Wind Energy (WE). PP informed the participants that Gian Piero Celata is in charge of representing the ENEA in the MoU. She has been charged by Massimo Busuoli, the coordinator of the General MoU JRC-ENEA, with coordinating other activities such as Environment and Nuclear issues. PP said a technical report describing the results of the new annex is expected by next summer. Maria Litido welcomed PP and, on behalf of the Director, Gabriele Zanini, presented the ENEA Technical Unit VALAMB (models, methods and technologies for the environmental assessment).

Lina Vitali,
ENEA UTVALAMB-IR



Massimo D'Isidoro,
ENEA UTVALAMBAIR

Luisella Ciancarella gave a brief overview of the MINNI project (National Integrated Modelling system for International Negotiation on atmospheric pollution[9]). This has been funded by the Italian Ministry of the Environment Land and Sea since 2002, under the responsibility of Gabriele Zanini. The main product is an integrated assessment modelling system aimed at both supporting the international negotiation process on air pollution and assessing air quality policies at national/local level by means of a more advanced understanding of atmospheric processes. The outputs of the project are used by the Ministry of the Environment in international negotiations on emissions reduction and the accomplishment of concentration thresholds according to the Kyoto protocol guidelines and international legislation.

[9] www.minni.org

One of the MINNI products is an open database (about 60 TB) of 3D meteorological and concentration fields. These refer to four different years with temporal resolution of one hour and spatial horizontal resolution of 20 km and 4 km. These data have been used with positive results by other institutions (regions, environmental agencies etc.) and private entities; for example, those in charge of environmental impact assessment of relevant works and infrastructures.

Fabio Monforti Ferrario, JRC – IET

Lina Vitali (LV) gave details of the MINNI meteorological module, which generated wind data for the project. She described the model used, the simulation set-up chosen, the validation procedure followed to identify the model performances and the data quality.

Fabio Monforti-Ferrario (FM) described the wind technical annex. The central objective of this is to develop, apply and evaluate a methodology to assess wind energy potential over Italy based on MINNI hourly wind fields at 4 km horizontal resolution, from ground level to tropopause.

The expected outcomes are:
1. Development of a software tool implementing wind energy potential computation;
2. Production of wind potential maps over Italy;
3. Report describing the methodology and the results obtained from the test over the Italian regions.

FM presented the first two outcomes achieved and a fruitful discussion by the participants followed. All stressed the originality of the results produced and the consistency of estimated yearly normalised potential for wind electricity production in 2005 in the Italian region (kWh/kW).

The next milestone of the project is a technical report. This will be embedded in a scientific paper and will describe the methodology and the results obtained from the test over the Italian domain. This report will present integrated wind speed and sun radiation patterns for the Italian domain and will describe their complementarity and implications for electricity generation. A first draft will be available by 30 November 2012 and a final version will be submitted by 31 December 2012.

A workshop presenting the results achieved within the MINNI project will be held in the ENEA, probably in December 2012.

Figure 6.1: Kick-off meeting, from left to right Lina Vitali, Massimo D'Isidoro, Luisella Ciancarella and Fabio Monforti Ferrario

Mid-term report 3 June 2013

Special interest in using the meteorological wind fields produced by the ENEA in the frame of the MINNI project (National Integrated Modelling system for International Negotiation on atmospheric pollution) as a base of data for testing methodologies developed inside the JRC for evaluating wind and the spatial and time correlation between wind power and solar power.

Results achieved so far:

1. Methodology developed and validated on the basis of a single meteorological year;
2. A peer-reviewed paper has been submitted;
3. Preliminary results were presented at the ENEA workshop on 17 April 2013.

Future steps:

1. Inclusion of more meteorological years to enlarge the base of data for case study;
2. Extension of the methodology by means of an ensemble forecast system.

Results

Assessing wind and sun potential complementarity in Italy

Introduction

The future role of wind and solar electricity in Italy and Europe

With Directive 2009/28/EC, the so-called Renewable Energy Directive (RED), European countries have accepted the challenge of making the European Union one of the most advanced group of nations in promoting renewable energies. Following the Directive, the 27 Member States of the European Union (EU-27) have to ensure that at least 20 % of the overall gross final energy consumption in the EU is of renewable origin in 2020. Moreover, each Member State also had to set out its strategy for reaching its own target in a detailed National Renewable Energy Action Plan (NREAP) presented to the European Commission before the end of 2010. The analysis of these plans (JRC, 2011) shows that wind and solar energies have an important role in the effort towards the 20 % target. The role of sun and wind as energy resources is expected to become even more crucial for renewable electricity generation: wind and sun together are expected to account for 49 % of renewable electricity gross production in 2020 for a total of 588 GWh (487 GWh from wind and 101 GWh from solar). It is also worth noting that 82 % of solar electricity in 2020 in the EU-27 is expected to be generated by photovoltaic (PV) systems, while the remaining 18 % will derive from concentrated solar power devices. In the case of wind, 73 % of the electricity will be generated with onshore wind towers while 27 % will derive from off-shore wind exploitation.

Italy is committed to a target of 18 % renewable energies penetration. Compared to the EU average pattern, renewable electricity generation in Italy shows some peculiarities. These include stronger hydro and geothermal sectors and a somewhat smaller increase in the 2020 overall renewable electricity production in comparison with 2005 data (+78 % in Italy against +149 % in the EU-27). Nevertheless, sun and wind are also expected to be a major source of renewable electricity in Italy. Combined production is expected to provide 30 % of the overall renewable electricity for a total of 31.3 GWh (20 GWh from wind and 11.3 GWh from sun); with PV accounting for 85 % of total solar power and onshore wind providing up to 90 % of wind electricity.

Sun radiation and wind both show an intermittent and partially unpredictable nature, so their combined use for generating the large amounts of electricity needed in future has to be carefully assessed. In order to be profitably exploited, intermittent uncontrollable generators have to be complemented by manageable fast-reacting power generators (mostly thermal) and efficient storage systems. For this reason, the complementarity of intermittent resources is a key issue for the overall power system: an expected strong wind and sun complementarity could save at least some of the costs of storage, and result in a less fluctuating and more even demand for traditional generation. Some studies have shown that geographically dispersed wind generators are more likely to provide a smooth supply profile, cancelling out random fluctuations. A more limited number of studies have addressed the issue of complementarity between wind and solar generation.

Rationale of the study and its history

In this study, wind speed and sun radiation patterns are investigated in the Italian territory in order to establish a basis for interpreting their common meteorological features and their implications for electricity generation. The study contains two main parts. In the first part, the complementarity of wind and sun in the same geographical location is investigated. In the second part, a generation system is simulated to evaluate the correlation of wind and sun electricity produced. This system is composed of both wind and sun stations at different locations. In order to avoid any bias towards a specific set of generation points, a Monte Carlo method has been implemented, whereby several equally probable sets of wind and sun farms are randomly generated in the chosen area, subject only to the constraint of a minimum amount of potential energy generated. Such an approach allows us to evaluate the intrinsic correlation between wind and sun resources, and is independent on the actual exploitation patterns chosen on the basis of other factors not investigated here. Different geographical areas could in principle be ranked in terms of the degree of complementarity one could expect when setting up distributed wind and sun generation systems.

Hourly wind fields for this study have been supplied by MINNI, which was developed by the ENEA (UTVALAMB-AIR) and has been managed by it on behalf of the Italian Ministry of the Environment since 2002 (Zanini et al. [2005]; Mircea et al. [2010]). The objective of the project is to support policy-makers in the elaboration and assessment of air pollution policies at international, national and local levels, by means of the more recent understandings of atmospheric processes. One of the MINNI products is the creation of an open meteorological and chemical database at national and regional levels to support analysis of regional and local atmospheric pollution. As an example, the annual averaged modelled wind field compared with observations is shown in Figure 1. This study represents the first usage of the meteorological database for an application different from air-quality assessment.

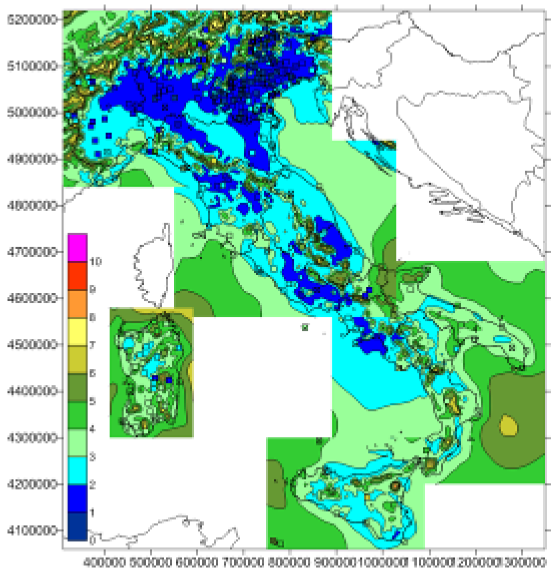


Figure6.2: 2005 annual mean wind speed (m/s): comparison between MINNI field and observations from the ISPRA-SCIA database (coloured symbols)

Results

A paper on Renewable Energy has been published (Monforti et al., 2014), presenting the main features of the correlation between sun and wind power.

At the beginning of the project, maps were produced on a national scale to describe the total annual PV and wind electricity production in terms of kWh produced per kW installed. The evaluation of complementarity between solar and wind resources for energy production has provided an important added value to the study, allowing an assessment not only of energy resources availability but also of their cost effectiveness.

As an example, results obtained for the Sardinia region are particularly interesting. Sardinia is characterised by a high availability of both solar and wind power (Figures 2 and 3).

However, it shows a less favourable correlation (i.e. a larger positive value of the correlation factor) behaviour than other regions, with correlation factors that are statistically significantly lower than the other regions and Italy as a whole (Table 1).

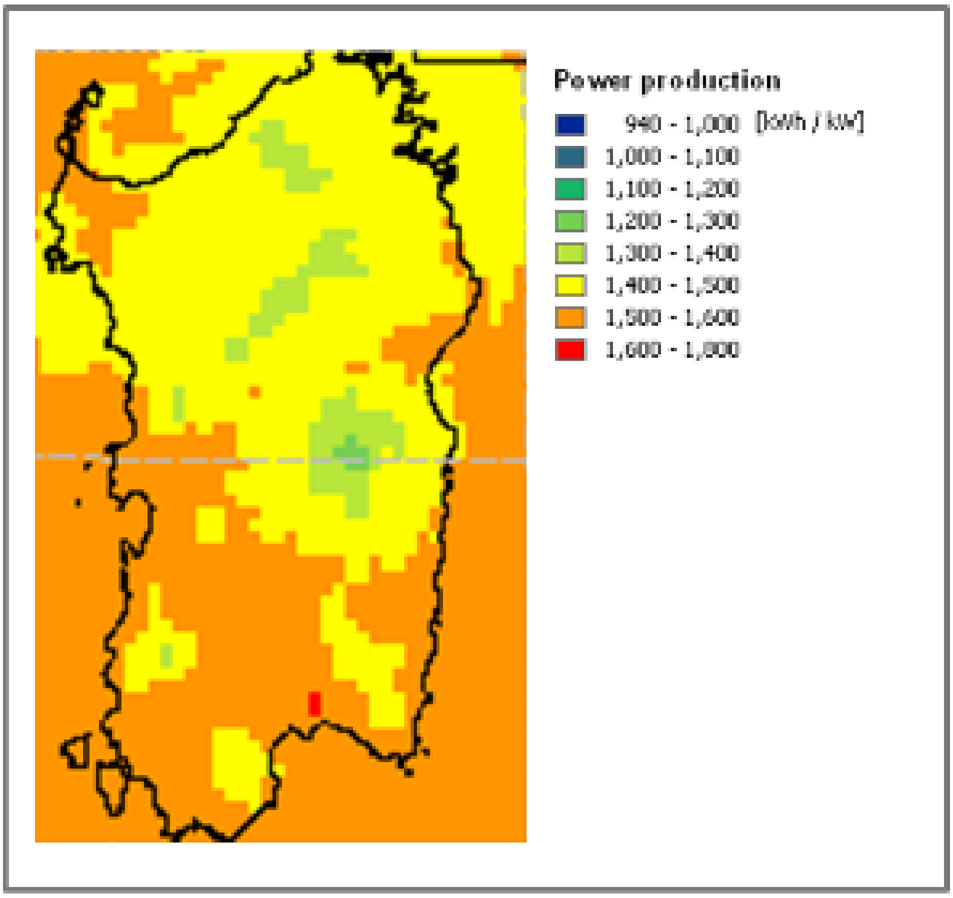


Figure 6.3: Estimated yearly normalised potential for PV electricity production in 2005 in the Sardinia region (kWh/kW)

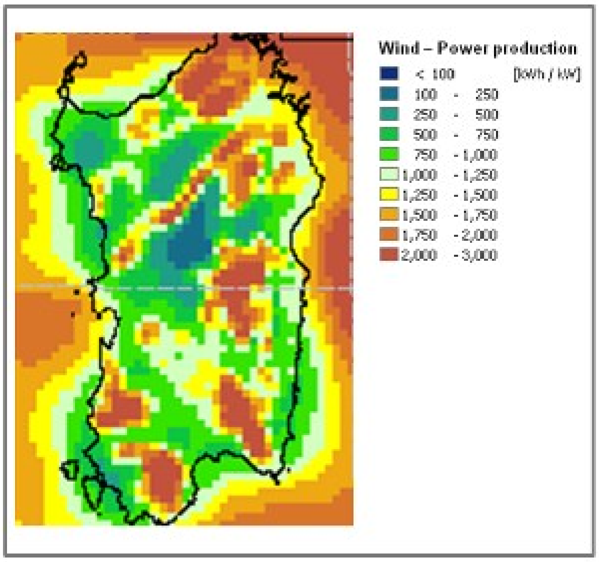


Figure 6.4: **Estimated yearly normalised potential for wind electricity production in 2005 in the Sardinia region (kWh/kW)**

	All Italy	**Sardinia**
Average monthly correlation	-0.63	-0.54
Minimum monthly correlation	-0.66	-0.57
Maximum monthly correlation	-0.61	-0.51

Table 6.1: **Examples of monthly wind-sun correlation in Sardinia and in the whole Italian territory for the year 2005.**

The results were presented during the workshop, Air quality in Italy: the MINNI National model as a support to international negotiations and regional policies, held in Rome on 17 and 18 April 2013.

Future developments

Future developments will include at the minimum the extension of the analyses to a larger number of meteorological years and, wherever possible, the use of higher-resolution meteorological fields.

The use of the Analogue Ensemble methodology (L. Delle Monache, 2011*)* to enhance the temporal span and spatial meaning of the study is also under discussion, while the correlation between sun and wind energy production and the national and regional demand for electricity should also be investigated in greater detail.

Figure 6.5: The **ENEA Workshop, Air quality in Italy: the MINNI National model as a support to international negotiations and regional policies, Rome (Italy) 17 and 18 April 2013. www.minni.org**

7. System Adequacy in the Power System Technical Annex

Project Leaders:	**for the JRC: Francesco Gracceva** **for the ENEA: Maria Rosa Virdis,**
Title and Short Summary	**System adequacy in the electricity sector. A multi-model approach.**
Objectives	**Development of the soft-link between the PLEXOS-Italy power and the TIMES-Italy energy system model — A Multi-Model Approach to System Adequacy in the Power System**

Kick-off meeting 14 September 2012

Francesco Gracceva,
JRC – IET

The kick-off meeting was a conference call between the ENEA sites in Rome and Ispra.
Participants for the ENEA were: Carlo Manna (CM), Patrizia Pistochini (PP), Maria Rosa Virdis (MRV), Umberto Ciorba, Maria Gaeta. For the JRC: Francesco Gracceva.
The meeting was introduced by PP, who gave an overview of the MoU between JRC and ENEA and informed participants that Gian Piero Celata represents the ENEA in the MoU.
Francesco Gracceva (FG) gave a brief overview of the project, whose objective is to develop a soft-link between a new PLEXOS-Italy power system model and the TIMES-Italy energy system model used by the ENEA. He explained how this link aims to overcome the limitations of TIMES models in the representation of the technical details of the power sector. However, the power sector model can benefit from the wide energy system approach provided by TIMES models.

FG described the main outcomes expected from the project:
- A new Plexos model of the Italian power sector consistent with the TIMES-Italy model;
- A scenario analysis of system adequacy in the Italian power sector under different energy-system scenarios, particularly under scenarios characterised by very high intermittent generation;
- A standardised procedure to build the PLEXOS power sector models consistent with TIMES energy system models.

FG stressed the originality and importance of the project: to his knowledge, there are no other examples of detailed Italian power system models linked to an energy system model. The standardisation of the procedure to link the two types of models will be a key preliminary methodological step to test the approach and extend it. The current project will facilitate the next step, which is to use combined TIMES and PLEXOS models to cover the whole European energy/power system.

CM agreed with FG, adding that he is already aware of national institutions that are potentially interested in taking advantage of the new approach to assessing system adequacy in the power system. He also stressed the importance of informing some key national energy stakeholders as soon as possible e.g. TERNA, the Italian transmission system operator.

The discussion moved on to a clarification and update on the roles of the ENEA and JRC in the project. CM and MRV agreed on a contribution from the ENEA equivalent to two persons-months, while FG confirmed all tasks within the JRC contribution described in the annex. He also confirmed that the JRC contribution would be three persons-months.

In conclusion, three milestones for the project were identified:

- A first technical report will be produced by the end of October, describing the procedure followed to build a first draft of the new PLEXOS-Italy model;
- A journal article on the main results of the scenario analysis will be drafted by 31 December 2012;
- A workshop will be held at the ENEA in November 2012, to present the project and its preliminary results to a selected panel of national experts.

Mid-term report 3 June 2013

1. Development of PLEXOS-Italy, a power system model, consistent with TIMES-Italy;
2. Standardisation of the procedure for data transfer from TIMES to PLEXOS;
3. Simulations of scenarios through the combined model to assess the security of the electricity supply.

Achieved results:

- A power system model for Italy based on PLEXOS (a power market simulation software) has been built, and is consistent with the TIMES-Italy model used by the ENEA;
- A scenario analysis to test the methodology and assess its added value and limitations: an energy system scenario derived from TIMES-Italy has been used as input for PLEXOS-Italy;
- Standardisation of the procedure to: a) build PLEXOS models consistent with TIMES models; b) soft-link the two models.

Next steps:

- Refinement of PLEXOS-Italy — transmission between market zones, flexibility instruments (Demand Side Management, storage, ancillary services), higher-resolution modelling (15-30 minutes), integration of the LT expansion plan with ST and MT analysis: simultaneous solution of the Generation & Transmission Capacity Expansion Plan with dispatch problem;
- Assessment of system and market adequacy through the combined TIMES-Italy/PLEXOS-Italy: effects of alternative energy system scenarios on power system operations and the power market; cost-benefit assessments of flexible resources and/or capacity expansion projects.

Introduction

Pushed by EU legislation, Europe's energy system has started to move towards a low-carbon, competitive and secure scenario. Security of supply, sustainability and competitiveness are the three complementary pillars of European energy policy, and are part of a common strategy. In recent years, increasing attention has been devoted to the need for adopting integrated approaches to energy policy-making. A wide range of policies has been introduced to pave the way towards a low-carbon energy system. The radical change envisaged by these policies however, may pose challenges to the security of the EU energy system. The recent EU Green paper on a 2030 framework for EU climate change and energy policies (COM[2013] 169 final, Brussels, 27.3.2013) states that: 'the 2030 framework must identify how best to maximise synergies and deal with trade-offs between the objectives of competitiveness, security of energy supply and sustainability' (COM[2013] 169 final, p.3). The current EU climate and energy targets were designed to be mutually supporting, and there are interactions between them. There are obvious synergies between the different targets, but also potential trade-offs.

To build a secure and sustainable energy future it is clearly necessary to ensure that the Commission's systemic vision is matched by the use of appropriate tools. These should be able to assess the complex interactions between climate change and energy security, so as to develop cost-effective strategies that maximise their results in both policy areas.

This JRC-ENEA project started from a theoretical approach to energy security, viewed as a multi-dimensional systemic property of the whole energy system. As the different dimensions of a secure energy system are correlated, the optimal/adequate level of security in any dimension cannot be found independently from the corresponding level in the correlated dimensions. The methodological implication of this theoretical approach is that, to properly assess the security of a power system, a combination of different techno-economic models is necessary.

As a consequence of this theoretical approach, the aim of this JRC-ENEA project has been to build a comprehensive multi-model approach to investigating energy security issues within power systems, based on a case study of the Italian power sector.

The core research activity has been the soft-linking exercise of the TIMES-Italy model to a dedicated power systems model. The purpose is to use the power systems model to investigate the system adequacy of the power system results that are produced from a range of energy system scenarios, i.e. consistent projections of the whole energy system; each solving in a different way the security problem of the long-term access to energy resources.

Two models of the Italian power system were developed in the PLEXOS Integrated Energy Model software to simulate operational results for the year 2020:

1. Aggregate input data from the TIMES-Italy model at hourly resolution were used to explore the insights that arise from increased time resolution;

2. More detailed information on power plants from the MONET (MOdello Nazionale Energetico TIMES) model developed by the Ricerca sul Sistema Energetico (RSE SpA), also at hourly resolution, has been used to explore the additional insights that arise from increased power plant resolution.

All models shared common inputs in the form of fuel prices, annual electricity demand, power plant portfolios and annual generation from renewable resources. A range of scenarios was simulated in all models to investigate the effect of a high carbon price on power system reliability and operation. Results were examined in terms of generation output by plant type, emissions by plant type and the overall reliability of the developed power system portfolio from TIMES.

The scenario analysis has been useful to test the methodology and assess its added value and limitations. Finally, the results of the project provided a standardised procedure for data transfer from TIMES to PLEXOS.

Results

All three milestones of the project have been achieved:

- Four technical reports have been published, describing the procedure followed to build a first draft of the new Plexos-Italy model, the results obtained and the open issues to be addressed in the future:
    - Technical Report I: a description of PLEXOS-Italy and discussion of results;
    - Technical Report II: the data transfer procedure from, and to, TIMES-Italy and PLEXOS, and specific data transfer for the specified scenarios;
    - Technical Report III: methodology and procedure to build a PLEXOS database from a TIMES database;
    - Technical Report IV: transmission planning component – pros and cons.
- Two JRC reports have been published: a scientific and policy report and a technical report.
- A draft journal article has been prepared.
- The results of the project were presented at the semi-annual ETSAP[10] workshop in Lisbon, on 10–11 December 2012.
- A workshop was held at ENEA in November 2012 to present the project and its preliminary results to a selected panel of national experts.

3.1 The soft-link between TIMES and PLEXOS

Figure 1 synthesises the procedure followed to link the TIMES energy system model with the PLEXOS power system model. For any alternative evolution of the whole energy system (with its associated total system costs) PLEXOS can provide relevant information on Security of energy systems. It does this by checking if, how and at what cost each TIMES energy system scenario fulfils the conditions for generation (and network) adequacy, i.e. the timing

[10] The Energy Technology Systems Analysis Program (ETSAP) is an Implementing Agreement of the International Energy Agency (IEA).

(and possibly even the location) of the ‘adequate’ level, type and characteristics of electricity generation and transmission.

Firstly, TIMES is used to provide a set of possible energy system scenarios, i.e. consistent images of the future energy system. Each image implies different characteristics of the power system e.g. the extent to which energy service demands are met through electricity, in competition with all other energy commodities. This takes into account interaction, mutual influence and dependency between electricity and gas markets and infrastructures. The scenario analysis provided by TIMES gives insights into the long-term dimensions of energy security, in terms of access to primary fuels and infrastructures and long-term balance between energy demand and supply. It also makes it possible to explore:

- The uncertainty surrounding key long-term drivers (technology, resources, economic growth etc.) and the way these drivers interact;
- Alternative energy and environmental policy;
- A simulation of stresses on a set of the more robust long-term scenarios.

Secondly, a subset of the most significant energy system scenarios (*reference* scenarios, *policy* scenarios, *stress* scenarios) is then selected. For each of these a specific year of the time horizon is selected and a set of data (key for the short-term resilience of the system) is passed to the PLEXOS model: the generation portfolio, electricity demand (after a proper transformation of the load curve), import/export of electricity and fuel prices.

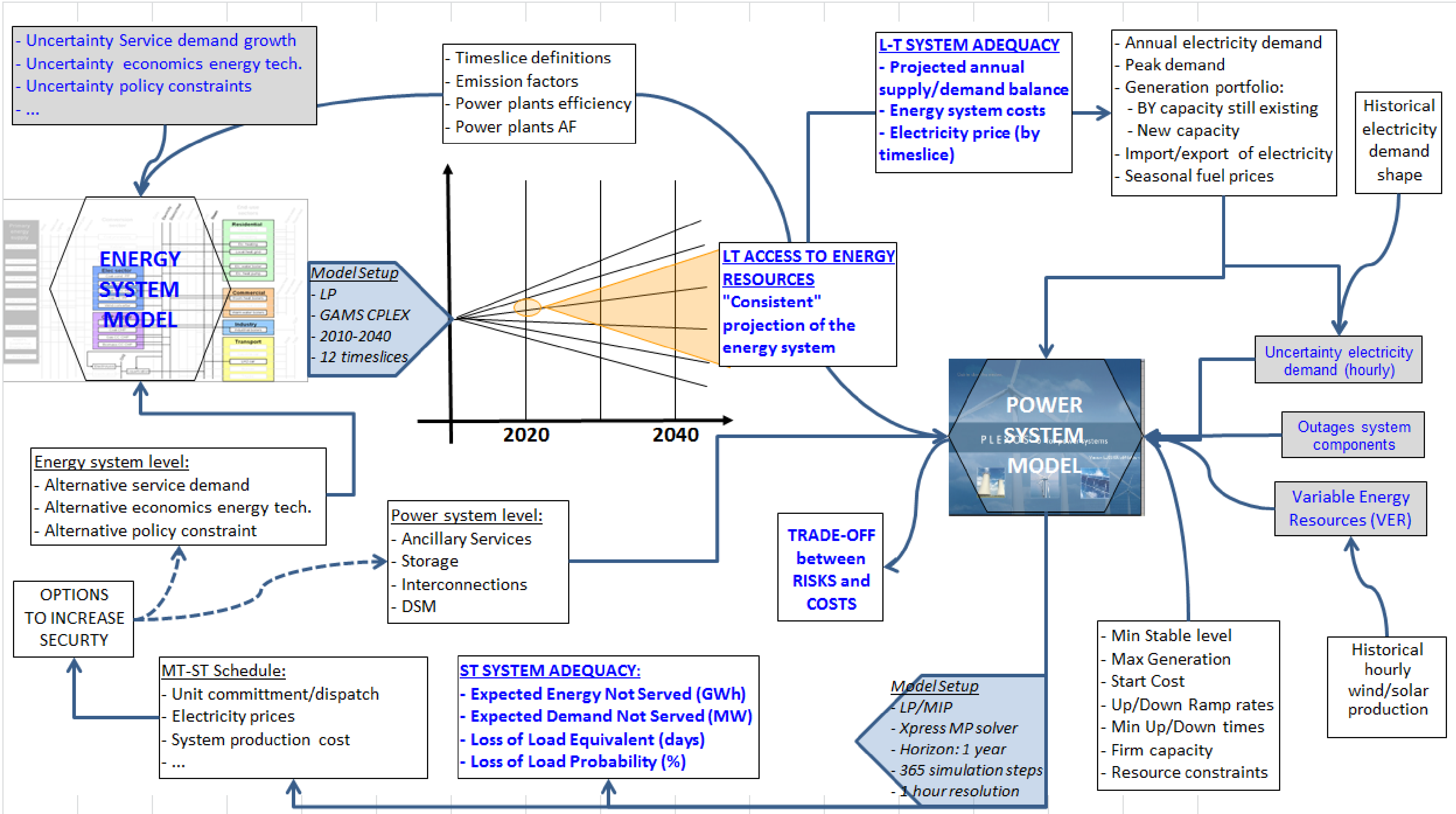
PLEXOS can now generate a more refined picture of the need for, and operation of, generation capacity in order to ensure different levels of energy security (each with an associated system cost). For any alternative evolution of the whole energy system (with its associated total system costs) PLEXOS is used to simulate if, how and at what cost each TIMES energy system scenario fulfils the conditions for generation (and network) adequacy, i.e. the timing (and location?) of the ‘adequate’ level, type and characteristics of electricity generation and transmission. PLEXOS results are assessed against the energy system cost of each system scenario, to explore how long-term drivers, policies and stresses affect system adequacy.

In sum, the integration of an energy system model with a power system model can provide insights into the ‘appropriate’ generating system associated with any given energy system. By focusing on standard PLEXOS outputs, such as loss of load probability (LOLP), energy not served (ENS) and electricity prices, under different scenarios, it is possible to evaluate system adequacy under a range of conditions. These include: long-term stresses (nuclear phase-out, high intermittency etc.) at the energy system level; policy-driven energy system scenarios (electrification, energy efficiency, Renewable Energy sources scenarios etc.). These scenarios meet policy objectives regarding both the other dimensions of energy security and the other pillars of energy policy (i.e. a low-carbon and competitive energy system).

Finally, the last step of the analysis is the assessment of the costs and benefits of the potential alternative strategies to increase system adequacy (under different energy system scenarios; policy driven or not). Through this, it should be possible to find the most effective and efficient mix of policies available at the energy system level, and of flexible instruments available at the power system level.

In conclusion, the soft-link between TIMES and PLEXOS combines a proper assessment of the technical characteristics of the functioning of a power system with the capacity to analyse the evolution of the whole energy system under a variety of scenarios. This process takes into account the interaction and mutual influence and dependency between the electricity and the other energy markets and infrastructures. Long capital-intensive projects, in particular, can be assessed carefully, looking at their costs and benefits in a market regime with high risk and uncertainty. For instance, it is possible to take into account the interaction and mutual influence and dependency between the electricity and gas markets, because gas prices affect the electricity market clearing. The same applies to electricity and gas infrastructures, because the extension of either infrastructure may also warrant an extension of the other.

Figure 7.1: The soft-link between the energy system model TIMES and the power system model PLEXOS



3.2 Model basics and scenario definitions

Two different PLEXOS models were developed during this soft-linking exercise, containing detailed information on a number of distinct model simulations. They enable a simulation of the Italian power system based on detailed information from two different TIMES models. Firstly, a PLEXOS-Italy model was built from the TIMES-Italy model. Building on the work of Deane et al. (2012), which offers insight into the benefit of high-resolution chronological simulation, this work also scrutinises different levels of aggregation within the database of power plants. To do so it uses the power plant database of the MONET model, which is populated with detailed information on all the main existing power plants in Italy and on those under construction (approximately 350 plants in total).

To assess the impact of a high level of Variable Energy resources on the functioning of the power system, an energy system scenario including a carbon tax has been simulated. The scenario uses fuel price and electricity demand from the 'With Tax' scenario run with the TIMES model. A carbon tax of EUR 250/tonne is applied.

This scenario forces the use of hourly wind and solar profiles in the TIMES simulations, as opposed to using the TIMES time-slice capacity factor definitions. The scenario also forces pumped storage units to be modelled as true Pumped Hydro Energy Storage units with a pump load, efficiency and storage reservoir, as opposed to hydro-limited resources with time-slice-dependent capacity factors.

Scenario Name	Description
TIMES Portfolio Only	This scenario forces the TIMES portfolios only. Must be used in conjunction with the 'With Tax TIMES portfolio'
With Tax TIMES Portfolio	This scenario forces the 'With Tax' TIMES portfolio
MONET Portfolio Only	This scenario forces the MONET portfolios only. Must be used in conjunction with the 'With Tax' MONET
With Tax MONET Portfolio	This scenario forces the 'With tax' MONET portfolio

Table 7.1: Scenario definitions

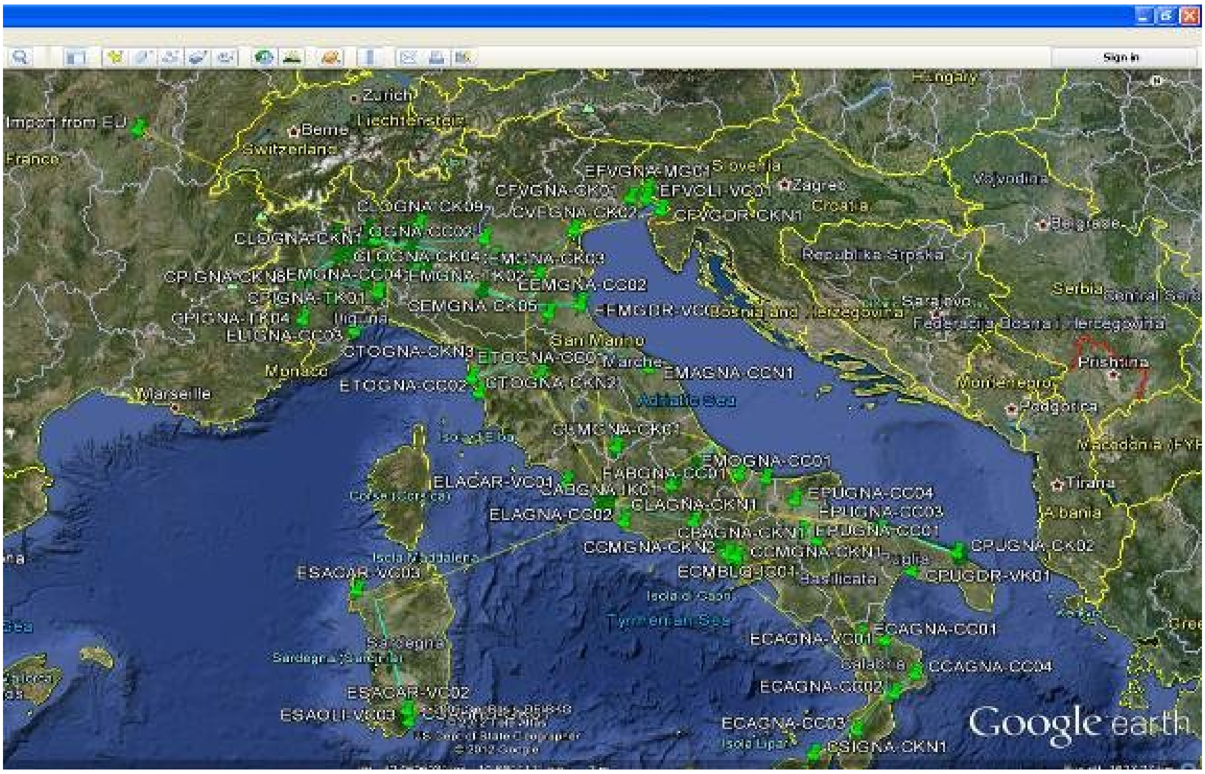


Figure 7.2: Google Earth representation of Power Plants in MONET

PLEXOS contains four distinct model simulations, as described in the following table. The simulations that are based on information from the MONET portfolio are called Disaggregated (or DisAgg for short) and simulations that are based on the Italian TIMES portfolio are called Aggregated (or Agg for short).

Model	Description
DisAgg Portfolio With Tax	This model contains the scenarios that will simulate the MONET With Tax portfolio and also model PHES units as true pumped storage units in place of time-slice-dependent capacity factors. A carbon tax of EUR 250/tonne is applied.
Agg Portfolio With Tax	This model contains the scenarios that will simulate the TIMES With Tax portfolio. Wind and solar are modelled as hourly time profiles, but can be changed to time-slice-dependent capacity factors by removing the scenario 'hourly wind and solar profiles TIMES'. A carbon tax of EUR 250/tonne is applied.

Table 7.2: Model simulations

3.2 Scenario results

The focus of this project was mainly on the soft-linking methodology. However, although far from definitive, the first results obtained already provide some interesting insights. When comparing results it is also important to look at how the two different datasets are used to build the models in PLEXOS, and to bear in mind that differences in final results can be due to fundamental model differences:

- The TIMES-Italy model is replicated very closely in PLEXOS Agg, and power plant capacities and efficiencies are the same in both.
- The PLEXOS DisAgg model was built using the MONET database; there are slight differences in power plant capacities (although overall capacities are equal) and power plant efficiencies, which drive changes in results.

Figure 3 shows the results in terms of generation output by fuel type for three models: the With Tax Scenario for the TIMES-Italy model and both the Agg and DisAgg PLEXOS model results.

The inclusion of a high-carbon tax has the effect of almost eliminating generation from the coal units. The Agg portfolio retains a higher level of coal generation because the size of the units and the technical requirements to stay online limit its ability to turn off quickly. The shortfall in generation is met by an increase of natural gas units and hydro-generation.

In terms of insights gained from the increased temporal and plant resolution from the PLEXOS models, the following points can be made:

Annual generation results for renewable sources, such as solar and wind, are similar in all model simulations, as all scenarios include the same carbon tax.

The increase in plant resolution leads to higher generation in some plant types due to the requirement that these plants provide peaking power at times of high demand, and also provide power when other units are out for maintenance or forced outage. For example the natural-gas-fuelled units in both scenarios provide a higher level of generation in the disaggregated cases, because the model sees these smaller plants as more flexible units that are not as technically constrained by minimum stable levels etc. such as the larger units in the Agg scenarios. Also, the inclusion of large 'bulky' plants and their associated technical constraints can lead to some units staying online longer than would be the case if these units were smaller. This can be seen for the heavy hydrocarbon plants, which are required to stay online for significant periods in the Agg cases.
Also, in terms of the evaluation of unserved energy, it is clear the Agg cases are unsuitable for the correct evaluation of this metric.

Other benefits from the increased temporal and plant resolution can be seen in terms of flexible plants, such as pumped storage, which require high temporal resolution to be modelled correctly. Hydro-generation is also lower for both the PLEXOS simulations; this occurs as the minimum stable level requirement and minimum up-time constraint requires thermal units to stay online even at times when larger portions of the load could be met by hydro resources. The inclusion of the pumped hydro storage units as 'true' units requires a higher load to be met in the DisAgg case. This is primarily met by the cheap base load units such as coal.

Other benefits that are not examined here, but can be inferred from the model, are the impact of cycling units and the curtailment of renewables.

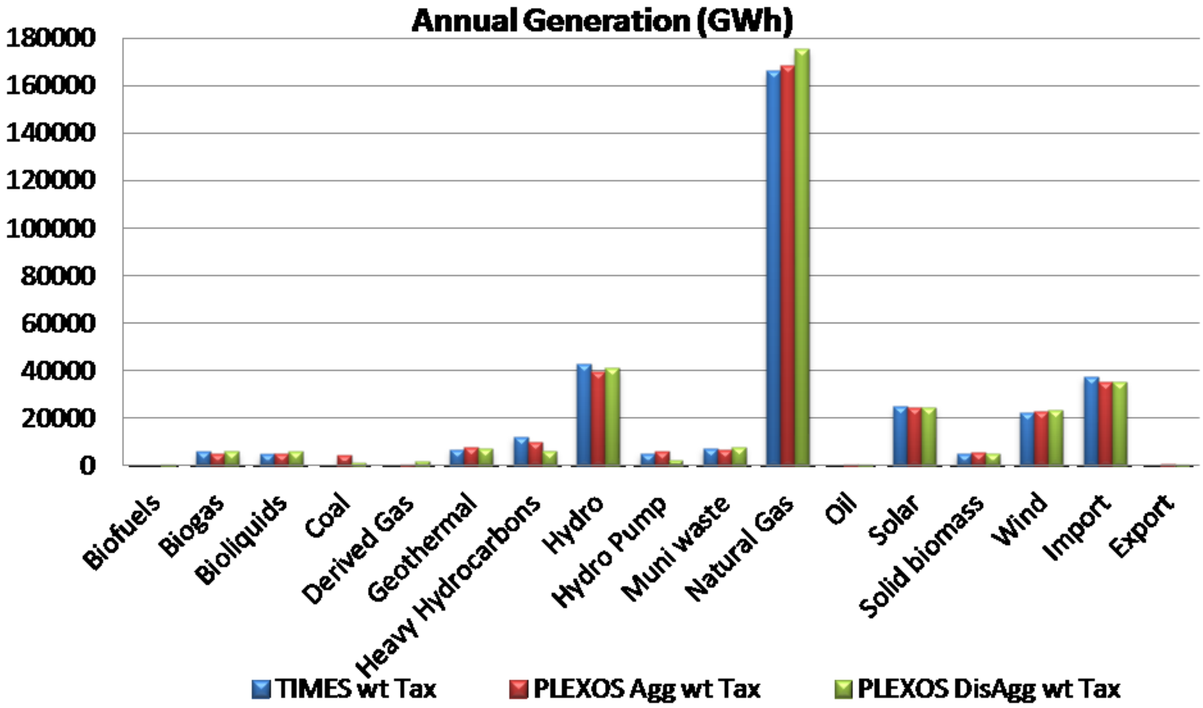


Figure 7.3: Annual Generation by Fuel Type for the With Tax Scenario

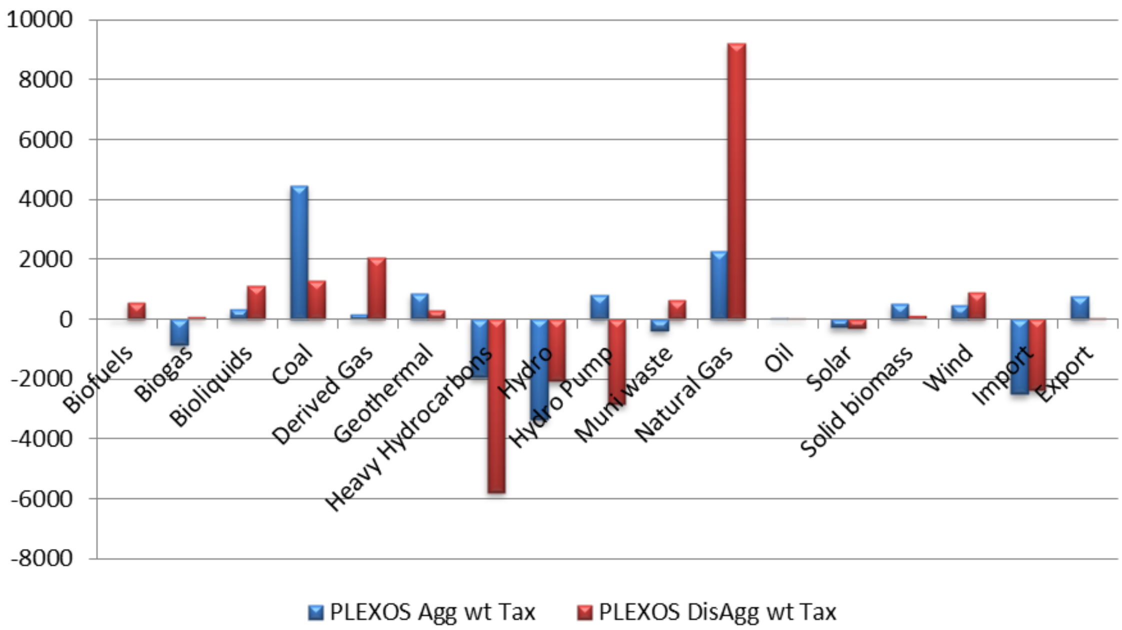


Figure 7.4: Difference in Annual Generation by Fuel Type for the With Tax Scenario

Results in terms of the annual emissions from each fuel type show that emissions for the DisAgg portfolio are significantly higher than for the Agg portfolio. This is because the emissions from the heavy-hydrocarbons-fuelled plant are not captured in Agg. Levels of natural gas and coal generation are similar for the TIMES and PLEXOS DisAgg models. However, it should be noted that the efficiencies for the gas plant from the MONET model are higher and lead to lower emissions, even though generation is higher.
Emissions for PLEXOS DisAgg are also higher than for TIMES-Italy, because the increase in coal emissions adds to the emissions total.

Fuel Type	TIMES wt Tax	PLEXOS Agg wt Tax	PLEXOS DisAgg wt Tax	
Biofuels	0	0	0	**Units**
Biogas	0	0	0	ktonne
Bioliquids	0	0	0	ktonne
Coal	0	2 770	1 197	ktonne
Derived Gas	0	0	0	ktonne
Heavy Hydrocarbons	0	0	0	ktonne
Muni waste	0	0	0	ktonne
Natural Gas	57 466	40 498	58 404	ktonne
Oil	0	82	40	ktonne
Solid biomass	0	0	0	ktonne
Total	**57 466**	**43 351**	**59 641**	**ktonne**

Table 7.3: Annual $C0_2$ emissions production by fuel type for the With Tax scenario

The power systems model PLEXOS is able to assess the generation adequacy of any modelled power system by the evaluation of projected assessment of system adequacy (PASA) reliability indices. Table 6 below details results of this assessment (n.b. the parameter firm generation capacity takes account of the capacity credit of wind/solar rather than its full nameplate capacity).

Both versions of PLEXOS models have quantities of unserved energy, and this would suggest that a closer examination of the reliability of the system is required. However, it is clear from these results that a disaggregated approach would lead to clearer results in term of reliability and adequacy assessment. In the Agg portfolio, the outages caused by large units can lead to unserved energy. Equally, the flexibility of the system is not captured and large units cannot change their output quickly enough to meet changes in net demand.

Reliability Index	TIMES wt Tax	Agg Portfolio wt Tax	DisAgg Portfolio wt Tax	
Peak Load	-	71 000	71 000	MW
Generation Capacity	-	141 222	141 223	MW
Firm Generation Capacity	-	114 179	114 122	MW
EENS (Expected Energy not Served)	-	6 810 495	5 285	MWh
EDNS (Expected Demand not Served)	-	1 193	0	MW
LOLE (Loss of Load Equivalent)	-	37	0	days
LOLP (Loss of Load Probability)	-	21	0.01	%

Table 7.4: Reliability results for the PLEXOS-Italy With Tax Scenario

Conclusions and next steps

The results of the analysis show how the soft-link between an energy system model and a power system model can provide useful insights into the main issues related to system adequacy in the power sector. However, to go beyond the methodological objective of the present paper, and to obtain more reliable results, the current model should be improved in a number of ways, including:

- The system examined has only been tested with one wind and solar production profile. Greater insights into the reliability of the system could be attained by simulating a number of production profiles, such as low-wind year versus high-wind year.

- The role of interconnection also plays an important role in the assessment of the reliability of the system, and the impact of increased interconnection should be further examined. The current version of the PLEXOS model assumed 13 000 MW of interconnection between Italy and the rest of the EU. Imports and exports (and thus indigenous power production) are sensitive to this value. The current model also assumed one interconnection point.

- The production of combined heat and power (CHP) units in the model is fixed by the TIMES-Italy availability factors. The accuracy of results could be improved by incorporation of the actual production profiles for these units.

- A number of stress tests should be performed on the disaggregated system to ascertain the sensitivity of the reliability of the system to changes in fuel price, renewable production and changes in consumer demand.

In conclusion, the first year of the project provided several useful pointers for the next steps. Consequently, the work programme for 2013 aims at refining PLEXOS-Italy by:

- Introducing transmission between market zones;

- Adding flexibility instruments (demand-side management, storage, ancillary services);

- Increasing the resolution of the model (15-30 minutes);

- Integrating the long-term expansion plan with short-term and medium-term analyses, to simultaneously solve the generation and transmission capacity expansion plan and the dispatch problem.

List of Publications

1. TA1 Photovoltaics Solar Electricity

- PAPERS

Galleano, R., Zaaiman, W., Strati, C., Bartocci, S., Pravettoni, M., Marzoli, M., Fucci, R., Leanza, G., Timò, G., Minuto, A., Catena, M., Aleo, F. Takagi, S. Akiyama, A., Nuñez, R. and Belluardo, G. 'Second International Spectroradiometer Intercomparison: results and impact on PV device calibration'. Submitted to *Progress in Photovoltaics.*

Galleano, R., Zaaiman, W., Virtuani, A., Pavanello, D., Morabito, P., Minuto, A., Spena, A., Bartocci, S., Fucci, R., Leanza, G., Fasanaro, D. and Catena, M. (2013), 'Intercomparison campaign of spectroradiometers for a correct estimation of solar spectral irradiance: results and potential impact on photovoltaic devices calibration'. *Progress in Photovoltaics*: Res. Appl. doi: 10.1002/pip.2361. First published online 12 February 2013.

- CONFERENCES

Galleano, R., Zaaiman, W., Morabito, P., Minuto, A., Spena, A., Bartocci, S., Fucci, R., Leanza, G., Pavanello, D., Virtuani, A., Fasanaro, D., Catena, M. and Norton M. 'Intercomparison of spectroradiometers for solar spectral irradiance measurements preliminary results'. *8th International Conference on Concentrating Photovoltaic Systems (CPV 8)*, 16 to 18 April 2012, Toledo, Spain. AIP Conf. Proc. 1477, 139–142 (2012); doi: 10.1063/1.4753853 http://dx.doi.org/10.1063/1.4753853.

Galleano, R., Zaaiman, W., Strati, C., Bartocci, S., Pravettoni, M., Marzoli, M., Fucci, R., Leanza, G., Timò, G., Minuto, A., Catena, M., Aleo, F., Takagi, S., Akiyama, A., Nuñez, R. and Belluardo, G. 'Second international spectroradiometer intercomparison: preliminary results and impact on PV device calibration'. *28th European Photovoltaic Solar Energy Conference (EU PVSEC),* 30 September to 4 October 2013, Paris, France. http://www.photovoltaic-conference.com.

Jointly organised event: Photovoltaics | Forms | Landscapes workshop at *EU PVSEC* http://www.photovoltaic-conference.com:

- 'Photovoltaics for shaping performative landscapes'. *26th European Photovoltaic Solar Energy Conference (EU PVSEC)*, 6 September 2011, Hamburg, Germany.
- 'How to use photovoltaics for shaping Nearly Zero Energy communities'. *27th European Photovoltaic Solar Energy Conference (EU PVSEC)*, 25 September 2012, Frankfurt, Germany.
- 'Beauty and power of designed photovoltaics', *28th European Photovoltaic Solar Energy Conference (EU PVSEC)*, 1 October 2013, Paris, France.

2. TA3 Bioenergy

- PAPERS

Scarlat, N., Motola, V., Monforti-Ferrario, F. and Dallemand, J.-F. 'Bioenergy production and use in Italy: Recent developments, perspectives and potential'. *Renewable Energy*, volume 57, September 2013, pp. 448–461. http://www.sciencedirect.com/science/article/pii/S0960148113000396.

Molino, A., Giordano, G., Motola, V., Fiorenza, G., Nanna, F. and Braccio, G. 'Electricity production by biomass steam gasification using a high-efficiency technology and low-environmental impact'. *Fuel*, volume 103, January 2013, pp. 179–192. http://www.sciencedirect.com/science/article/pii/S0016236112005340.

- CONFERENCES

Motola, V. and Petrone, M.T. 'Local Availability of Lignocellulosic Biomass and Animal Wastes'. *20th European Biomass Conference and Exhibition*, 18 to 22 June 2012, Milan, Italy. http://www.conference-biomass.com/.

3. TA4 SETIS - Strategic Energy Technologies Information System

- PUBLICATIONS

Capacities Map 2013 http://setis.ec.europa.eu/setis-deliverables/capacity-mapping/2013
Project Mapping 2013 http://setis.ec.europa.eu/setis-deliverables/project-mapping
Energy Research Knowledge Centre project, policy brochure: 'Overcoming Research Challenges for Ocean Renewable Energy', 2013
http://setis.ec.europa.eu/energy-research/content/policy-brochures.

- CONFERENCES

Sherpa group of the European Community Steering Group of SET-Plan, 11 April 2013, Brussels, Belgium.

4. TA6 Net Zero Energy Building

- PUBLICATIONS

Bloem, H., Bacher, P., Scognamiglio, A., Strachan, P. and Valdaele, I. 'High performance buildings — Design and Evaluation Methodologies'. Summary report.

o CONFERENCES

Bloem, H. and Scognamiglio, A. 'High-performance buildings. A feasible option for future cities?' Joint presentation at the *World Sustainable Energy Days — Nearly Zero Energy Buildings* conference, 28 February to 1 March 2013, Wels, Austria.
http://www.wsed.at/en/world-sustainable-energy-days/
http://www.wsed.at/en/reviews/wsed-2013/programme/nearly-zero-energy-buildings/
http://www.wsed.at/fileadmin/redakteure/WSED/2013/NZEB_Programme.pdf.

Joint organisation (JRC – ENEA – INIVE/DYNASTEE) of international conference: *High-Performance Buildings - Design and Evaluation Methodologies*. On the occasion of European Sustainable Energy Week (EUSEW), 24 to 26 June 2013, Brussels, Belgium.
http://iet.jrc.ec.europa.eu/energyefficiency/workshop/workshop-high-performance-buildings-design-and-evaluation-methodologies
http://www.enea.it/it/enea_informa/events/highperfbuildings_24-26giu13/high-performance-buildings-design-and-evaluation-methodologies.

5. TA8 E-MOBILITY

- PUBLICATIONS in progress
- CONFERENCES in progress

6. TA 9 Mapping of wind resources

- PAPERS

Monforti-Ferrario, F., Huld, T., Bódis, K., Vitali, L., D'Isidoro, M. and Lacal-Arántegui, R. 'Assessing complementarity of wind and solar resources for energy production in Italy. A Monte Carlo approach'. *Renewable Energy*, volume 63, March 2014, pp. 576–586. ISSN 0960-1481,
http://dx.doi.org/10.1016/j.renene.2013.10.028.
http://www.sciencedirect.com/science/article/pii/S0960148113005594.

- CONFERENCES

ENEA Workshop. *Air quality in Italy: the MINNI National model as a support to international negotiations and regional policies*. 17 and 18 April 2013, Rome, Italy. www.minni.org.
http://www.minni.org/conferenza-finale-minni/Evento-MINNI_Flyer-agenda-eng_12032013.pdf
ENEA press release and Web TV. '*Il sistema MINNI dell'ENEA per la valutazione della qualità dell'aria*'. http://titano.sede.enea.it/Stampa/skin2col.php?page=comunicatodetail&id=573.

7. TA10 SAPS – System Adequacy in Power System

- PUBLICATIONS

Deane, J.P., Gracceva, F., Chiodi, A., Gargiulo, M. and Ó Gallachóir, B.P. *A multi-model approach to Power System Security*. JRC Scientific and Policy report. (References are not yet available.)

Deane, J.P., Gracceva, F., Chiodi, A., Gargiulo, M. and Ó Gallachóir, B.P. *Modelling Power System Energy Security By Soft-Linking TIMES with PLEXOS*. JRC Technical report. (References are not yet available.)

- CONFERENCES

Deane, J.P., Gracceva, F., Chiodi, A., Gargiulo, M. and Ó Gallachóir, B.P. 'Modelling Power System Energy Security by Soft-Linking TIMES and PLEXOS'. *Semi-annual ETSAP meeting*, 10 to 11 December 2012, Lisbon, Portugal.http://www.iea-etsap.org/web/Lisbon_Dec2012.asp

ENEA internal workshop to a selected panel of national experts. '*Sicurezza energetica nel settore elettrico: un approccio modellistico con TIMES e PLEXOS*.' 23 November 2012, Rome, Italy.

European Commission
EUR 26723 EN – Joint Research Centre – Institute for Energy and Transport

Title: **Results of the IET-ENEA implementation of the JRC-ENEA Memorandum of Understanding**

Edited by: H. Ossenbrink and G.P. Celata

Luxembourg: Publications Office of the European Union

2014 – 104 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series –ISSN 1831-9424 (online), ISSN 1018-5593 (print),

ISBN 978-92-79-39140-8 (PDF)
ISBN 978-92-79-39141-5 (print)

doi: 10.2790/28962 (online)

LD-NA-26723-EN-N

JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

Serving society
Stimulating innovation
Supporting legislation

Publications Office

doi: 10.2790/28962
ISBN 978-92-79-39140-8